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ELEMENTARY

PRACTICAL BIOLOGY

VEGETABLE

BY

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PREFACE.

In conducting during the past three years the courses of instruction in Biology at St. Bartholomew's Hospital, I have found the want of a concise book which could be used as a guide to the practical laboratory work. The excellent practical books by Huxley and Martin, Parker, and Bower and Vines, to a certain extent supply the practical directions, but they are imperfect in not treating of all the types of animal and vegetable life required by an elementary student, nor are they arranged on the plan which I have found best in teaching.

This want I have remedied to a certain extent by means of short lithographed or printed directions, and, at the solicitation of many of my past students, I have resolved to amplify these practical directions, and to publish them in a concise form. The present volume represents the first, or Vegetable, part of a complete elementary practical book on Biology, and will be found to give practical directions for working with all the types required in the vegetable part of the Elementary Biological Examinations at the London University.

At one time I contemplated writing a text-book on Elementary Biology, but abandoned this as being not unlikely to foster "cram," and, feeling sure that all knowledge in Biology must be acquired practically, I have endeavoured to so write this book as to prevent "cram." For this reason I have avoided all illustrations.

The only originality I claim in this book is the arrangement and treatment of the subject. I have to express my indebtedness to the works of Sachs, Huxley and Martin, Vines, and Bower and Vines, which I have frequently made use of for reference.

T. W. S.

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ELEMENTARY PRACTICAL BIOLOGY.

INTRODUCTION.

The Student of Vegetable Biology, who wishes to obtain a real knowledge of the subject, can only do this by systematic laboratory work. In performing the following exercises a certain amount of manipulative skill is necessary, and this can only be acquired by practice. Vegetable structures can sometimes be examined in their fresh condition, but generally some preliminary preparation is necessary. In order to become acquainted with these preliminary details, the student should familiarise himself with general practical methods by carefully studying the following account before beginning the systematic exercises.

APPARATUS REQUIRED.

The student should provide himself with the following :—

1. A *Microscope.* The £5 5*s.* Students' Microscopes, by Crouch, of Barbican, and by Stanley, are recommended, but any simply constructed instrument, provided with good objective glasses of 1 inch, $\frac{2}{3}$ inch, or $\frac{1}{2}$ inch power, together with $\frac{1}{6}$ inch or $\frac{1}{8}$ inch, will be found to be all that is required.
2. *Dissecting Needles* mounted in wooden handles.
3. A *Razor*, preferably with the under surface ground *flat.*
4. *Camel's Hair Brushes.*
5. *Watch-glasses.*
6. A *Section Lifter.*
7. A pair of *Fine Forceps* and a small pair of *Scissors;* also a small *Scalpel.*
8. *Slides*, of usual size, and thin *Cover-slips.*

PREPARATION OF VEGETABLE TISSUES.

Vegetable Tissues may be examined either in the fresh state or after some preparation. Most of the structures required in working over the following exercises are best if they have been previously kept in alcohol. This has the effect of—

1. Removing the green colouring matter, and so rendering the tissues clearer.
2. Removing any air-bubbles which may happen to be in the tissues of a plant.
3. Hardening the tissues by removing water.
4. Preserving them.

It is convenient, in supplying materials for a class, to preserve in spirit plants or parts of plants which might not otherwise be obtainable when required.

If it is wished to isolate the various kinds of cells which compose a tissue, it is best to macerate the part in Chlorate of Potash and Nitric Acid (Schultz' macerating solution), which has the effect of dissolving the common cell wall and so isolating the individual cells.

Sometimes it is desirable to specially harden tissues. This is done with either Chromic or Picric Acid, or with absolute Alcohol. The latter usually renders tissues brittle and difficult to cut. To obviate this, the object should be placed in Glycerin for some hours before it is cut. When Chromic or Picric Acid is employed, the object should remain in an excess of the fluid for about twenty-four hours; should then be washed in Alcohol as long as any colour can be extracted, and finally preserved in Alcohol.

IMBEDDING.

In cutting sections of a small organ which cannot be conveniently held in the fingers, or which is too soft to permit of the cutting of thin sections, it is necessary to support the organ by imbedding it in some substance sufficiently large to be conveniently held, and hard enough to enable thin sections to be cut. In such cases, it is convenient to place the object between two pieces of carrot or potato, or between two layers of dry elder-pith, and then cut sections of the imbedding substance and the object in it. Or wax, of various consistency, may be used.

If wax is used, a mixture of white wax and olive oil, in equal parts, melted together and run into blocks and allowed to cool, should be employed.

Or a mixture of paraffin wax and lard, in varying proportions according to the consistency required, will do as well. Cacao butter is also used for this purpose.

When you wish to imbed a tissue in wax it should have previously lain in spirit for a day or two. It should then be transferred to turpentine, the excess of spirit being removed with blotting-paper. Then scoop a hole in the extremity of a lump of wax, sufficiently large to take the object to be imbedded.

Next, immerse the object for a short time in molten wax (not too hot), and place in the hole in the block of wax, pouring around it some molten wax so as to cover the object. Allow to cool. After cutting your sections, float them first into turpentine to dissolve the wax, then into spirit before mounting.

When sections are cut with a microtome, the object may either be imbedded in wax; or the freezing method may be adopted. If this method is used, Williams' microtome is employed; the object should be left in water for about twelve hours to abstract the alcohol, and then placed on the metallic plate of the microtome in a little gum. The gum soon becomes frozen by means of the ice in the microtome, and the object thus fixed for cutting.

SECTION CUTTING.

In the following exercises it is not necessary to employ the more perfect means for cutting sections, viz., Microtomes. All that is required is a sharp razor. The student should be sure that the razor is very sharp, and it is preferable to have one which has been ground flat on its under surface. Hold the razor firmly in the right hand with the fingers closed above the handle, which should be kept in a line with the blade. Take the object to be cut, whether imbedded or not, between the thumb and index finger of the left hand. Support the back of the razor on the index finger, and cut from left to right, and from heel to tip of razor. Take care to keep the blade and object well wetted with spirit, and as each section is cut, float it from the razor into spirit in a watch-glass, by means of a camel's hair brush. A little practice will enable the student to cut sufficiently thin sections.

STAINING OF SECTIONS.

Although most vegetable structures are to be clearly seen without staining, yet it is sometimes desirable to render them more distinct by employing various staining fluids. Those staining reagents are of greatest value which only colour certain particular structures, and thus differentiate the various tissues when they are obscure. The stains most commonly used are—

I. *Iodine.*—This should be employed in a watery solution with Iodide of Potassium, and stains protoplasm dark *brown*, leaving the cellulose cell walls only very faintly stained, if at all. It, however, stains readily lignified and cuticularised cell walls.

II. *Schultz' Solution.*—This is a very valuable solution as a test for cellulose cell walls. These it stains *blue*, whilst lignified and cuticularised cell walls are stained by it of a *yellow* or *brown* colour. It also stains protoplasm *brown.* The cell walls in the phloëm of fibro-vascular bundles are chiefly of cellulose, whilst those of the xylem are mostly lignified. It is thus useful in differentiating between these two parts of the bundles.

III. *Hæmatoxylin*, or *Logwood.*—This reagent stains the *nuclei* especially, also the protoplasm of the vegetable cells; and any of the very various solutions of logwood may be used. It may be employed either for fresh or for preserved tissues; but those hardened in Chromic or Picric Acid sometimes are difficult to stain with this reagent.

IV. *Magenta.*—This is not a very valuable staining substance, as it colours all the tissues alike.

V. *Carmine.*—Either the ammoniacal or the borax carmine may be employed. It is particularly useful to show up the nuclei of cells.

VI. *Aniline Colours.*—Of these, those chiefly employed are *eosin*, *methyl-green*, *methyl-violet*, *Spiller's purple*, *fuchsin*, and *methylene-blue.* Eosin is used as a stain for protoplasm, and very often for demonstrating the continuity of protoplasm from cell to cell, *e.g.*, in sieve tubes. Methyl-green chiefly stains the nuclei and protoplasm of the cells. Methyl-violet is also used for staining protoplasm. Spiller's purple is of value for the same purpose. Fuchsin is employed for the staining of cell walls, and particularly the cuticularised cell walls. A section stained in fuchsin is decolourised on treating with alcohol in all parts except the cuticularised cell walls. Methylene-blue stains the cell walls, and leaves the protoplasm untouched. By employing two stains which attack only certain structures, the various parts may be brought out in different colours. This method of double staining is very useful. Many of the above aniline stains are employed in the study of bacteria.

Whatever staining fluid is used, may be employed in one of two ways. (*a.*) By taking a little of the fluid in a watch-glass and placing the sections in it for a time varying with the strength of the solution. It is always best to expose a section for a long time to the action of a dilute stain, rather than a shorter time with a stronger staining fluid.

(*b.*) By *irrigation.* This method is employed when it is desired to watch the action of a staining fluid. A drop of the fluid is placed on the slide at one side of the cover-glass, and then drawn through by means of a piece of blotting-paper at the opposite side of the cover.

PREPARATION OF SECTIONS.

Ordinarily, it is only necessary, after cutting the sections, to mount them directly in some mounting fluid. But sometimes the sections are not sufficiently transparent for minute examination, especially with high powers; it is then necessary to *clear* them, *i.e.*, render them more transparent. Most commonly this is done by means of a dilute solution of Potash, which causes cell walls and protoplasm to swell up. It also dissolves fat globules by saponifying them. When it is desired to clear a section in Potash, it should be placed in a little of the solution in a watch-glass, and subsequently washed in water before mounting.

In the case of sections of tissues which have been hardened in Picric or Chromic Acid, especially if they have been stained and it is desired to keep them permanently, the following process is employed. After staining, they are washed in water, then placed in methylated spirit, then transferred to absolute alcohol. The object of this is to *dehydrate* the specimens. After lying in absolute alcohol for a few minutes they are placed in oil of cloves, which has the effect of *clearing* them. Specimens cleared in this way should be mounted in *Canada balsam.* A mixture of turpentine and creosote may be employed instead of clove oil.

In working the following exercises, should the student find his sections to be opaque he should, unless instructed to the contrary, clear them in Potash.

MOUNTING OF SECTIONS.

For examining sections with the microscope the student will require :—

Glass Slides, three inches long and one inch wide.

Cover-glasses, of very thin glass, about $\frac{3}{4}$ inch in diameter.

A *Section Lifter*, consisting of small thin plate of metal provided with a handle.

A *Needle.*

And some suitable *Mounting Solution.*

When it is desired simply to examine a tissue in its fresh state, sections or objects can be mounted in water. But, as a rule, the medium employed in these exercises is *glycerin*, or *glycerin-jelly.* In mounting in glycerin, take a drop on the middle of a glass slide, and then transfer the section from spirit, in a watch-glass, to the slide, by means of a section lifter.

Then carefully drop over the specimen a thin cover-glass. If it is desired to keep the section permanently, the cover-glass should be painted round with Canada balsam or some other cement.

Specimens which have been cleared by means of potash should be mounted in *glycerin.* Sections stained in logwood may be mounted either in glycerin or in Canada balsam. If in the latter, they must be previously cleared by the clove oil process. Those stained in carmine may be mounted in the same way. Sections stained in the aniline dyes are usually mounted in Canada balsam. *In all cases, if sections are mounted in balsam, they must be cleared by the clove oil method.* In the following exercises, unless directions are given to the contrary, the specimens should be examined by mounting in glycerin.

PREPARATION OF REAGENTS.

1. *Pasteur's Solution.*

Ammonium Tartrate ...	... 10	parts.
Cane Sugar	... 150	,,
Potassium Phosphate ...	... 2	,,
Calcium Phosphate ...	... ·2	,,
Magnesium Sulphate ...	... ·2	,,
Water	... 837·6	,,
	1000·0	,,

2. *Iodine Solution.* Dissolve Iodine and Iodide of Potassium in distilled water, and dilute with water till the solution is of a dark sherry colour.

3. *Logwood Solution.*—Grind together in a mortar 5 grammes of Alum and 5 grammes of extract of Logwood, with 100 c.c. of distilled water. Leave for 24 hours. Filter and keep in a stoppered bottle.

4. *Schultz' Solution.*—Dissolve metallic Zinc in Hydrochloric Acid. Evaporate slowly to a syrup with metallic Zinc. Saturate syrup with Potassium Iodide, and then with Iodine. When required, dilute with distilled water till the solution is of a dark sherry colour.

5. *Canada Balsam.*—Mix together equal parts of Canada Balsam and Chloroform, and warm gently.

6. *Glycerin.*—Ordinary commercial Glycerin, or this may be diluted with its bulk of water.

7. *Sulphuric Acid.*—Strong Sulphuric Acid diluted with about its bulk of distilled water. This may be diluted if necessary.

8. *Magenta Solution.*—Dissolve one gramme of Magenta in 500 c.c. of water, and add about 10 c.c. of Alcohol. Dilute when required.

9. *Carmine Solution.*—Dissolve one gramme of Carmine in 12 c.c. of water and 1 c.c. of strong Ammonia. Dilute when required with about 20 times its bulk of water.

10. *Borax Carmine.*—One gramme of Carmine and four of Borax are dissolved in 50 c.c. of distilled water. Filter. Add 100 c.c. of Alcohol.

11. *Eosin Solution.*—Saturated alcoholic solution of Eosin.

12. *Methyl-green Solution.*—Saturated alcoholic solution of Methyl-green, diluted when required.

13. *Methyl-violet Solution.*—Saturated alcoholic solution of Methyl-violet, diluted when required with water.

14. *Spiller's Purple Solution.*—A strong solution of Spiller's purple in water, diluted when required.

15. *Fuchsin Solution.*—Saturated alcoholic solution, diluted when required.

16. *Methylene-blue Solution.*—Saturated watery solution, diluted when required.

17. *Schultz' Macerating Solution.*—One gramme of Chlorate of Potash dissolved in 50 c.c. of strong Nitric Acid.

18. *Solution of Potash.*—Five grammes of Caustic Potash dissolved in 100 c.c. of water.

GENERAL DIRECTIONS.

1. Be clean and tidy in your work, and have all apparatus, slides, watch-glasses, cover-slips, &c., scrupulously clean.

2. Always keep your razor sharp, and do not allow fragments of tissue to dry upon it. Always strop it in the same direction.

3. In cutting sections always keep your razor well wetted.

4. Let your sections be as thin as possible.

5. Use your section lifter to transfer sections from one reagent to another.

6. Do not take too much glycerin on your slide in mounting a specimen.

7. Always place a drop of the mounting fluid on your slide *before* you put your specimen on it.

8. See that your lenses are always kept free from dust.

9. If Canada balsam accidentally get on to your object-glass, remove it by means of spirit. Do not rub it off with a cloth, or your lens may be scratched.

10. Always be sure that you see what is described.

11. Make drawings of every object examined.

PART I.

GENERAL VEGETABLE MORPHOLOGY.

i. Vegetable and Animal Cells.

i. Take a drop of Pasteur's fluid in which some baker's yeast has been sown a few hours previously: Place on a glass slide and cover with a thin cover-glass. Examine with a high power ($\frac{1}{6}$ or $\frac{1}{8}$ inch objective).

Observe :—

a. The size and shape of the **Torula** cells.

b. Their structure.

1. The *cell wall*—transparent.
2. The *protoplasm*—slightly granular.
3. The *vacuole*—its size, form, position.

Draw.

ii. Irrigate your specimen with Iodine solution.

Observe :—

a. What parts stain. Cell wall remains unchanged; protoplasm stains brown; vacuole unaffected.

b. Absence of any blue coloration.

iii. Irrigate another specimen with logwood or with carmine solution.

Observe :—

That the protoplasm stains, the rest of the cell remaining unaffected.

iv. Press sharply on the cover-glass of your preparation, and examine again.

Observe :—

a. The empty burst unstained cell wall.

b. The stained crushed protoplasm.

v. Place on a slide a drop of water containing **Amœbæ.** Cover with a cover-glass and examine with a high power.

Observe :—

a. The *size* of the Amœbæ—variable.

b. The *form*—irregular, changeable.

c. The protrusion and retraction of *pseudo-podia.* Draw.

d. *Structure*—

1. Sharp outer hyaline transparent *ectosarc* ; more granular inner *endosarc.*
2. *Nucleus*—a rounded solid particle in the endosarc.
3. The *vacuole*, lying in the ectosarc. It disappears rhythmically, and then slowly reappears.
4. *Food particles* in the endosarc.

vi. Irrigate with *Iodine* or *hæmatoxylin.*

Observe :—

a. The *whole* stains.

b. Absence of an unstained cell wall.

c. No blue coloration.

vii. *Crush.* There is no outer uncrushed, burst cell wall.

---

ii. Vegetable Cells—The Cell Wall.

i. Practise cutting sections on a piece of potato or of carrot.

ii. Cut thin transverse sections of the leaf of **Laurel.** Mount in glycerin, and cover.

Observe :—

a. The characters of vegetable cells.

b. The *common cell wall*, forming a very thin lamella between adjacent cells and *common* to each.

c. The *cuticle* or outer cell wall of the cells at the surface, and forming a continuous layer over the surfaces of the sections.

d. *Stratification* of the cuticle, *i.e.*, the appearance of lines in it, parallel to the surface of the section, due to the alternation of layers of cell wall of different densities.

iii. Stain a section with Iodine.

Observe :—

The absence of, or only slight staining of the cell-wall.

iv. Stain with Iodine and Sulphuric Acid (about 25–50 p.c.), and mount in water.

Observe :—

a. The *blue* coloration of the cell wall (cellulose.)

b. The *yellowish brown* coloration of the cuticle (cutin).

v. Stain a section with Schultz' solution, and mount in water.

Observe :—

a. The *blue* coloration of the majority of the cell walls (cellulose).

b. The *yellow* coloration of the cuticle (cutin).

vi. Cut thin transverse sections of a piece of **Cork,** mounting them in glycerin.

Observe :—

The empty shrivelled cell walls devoid of protoplasm or nucleus.

Stain one with Iodine and Sulphuric Acid, and mount in water.

Observe :—

The *yellowish brown* coloration of the cell wall (cutin).

Stain one with Schultz' solution, and mount in water.

Observe :—

The *yellowish* colour assumed by the cell wall.

vii. Cut thin transverse sections of the wood of **Pinus**, and stain one with Iodine alone, and another with Iodine and Sulphuric Acid, mounting in water.

Observe :—

The cell walls in the former do not stain ; in the latter stain *brown* (lignin).

viii. Stain a section of the wood of **Pinus** with Schultz' solution, and mount in water.

Observe :—

Yellowish-brown coloration of the cell wall.

iii. Vegetable Cells—The Cell Wall (Continued).

i. Cut thin longitudinal sections of the stem of **Cucurbita,** taking care that the sections pass radially through the fibro-vascular bundles. Mount some in glycerin, and examine first with a low power, afterwards with a high one. In the more internal parts of the fibro-vascular bundles,

Observe :—

The various kinds of thickening of the cell walls, giving rise to :—

a. *Spiral* thickenings, continuous bands of thickening projecting into the cell from the inner surface of the cell wall.

b. *Reticulated* thickenings.

c. *Annular* ,, complete isolated rings of thickening.

In some cells observe, also, a regular dotted appearance, due to unthickened pits in the cell walls (*pitted-cells*).

Draw carefully the various kinds of thickening.

ii. Cut thin longitudinal sections of the rhizome of **Pteris** (Bracken fern), taking care that the sections pass through the fibro-vascular bundles.

Observe :—

a. Certain large elongated cells (united into vessels), with regular transverse thickenings in their walls (*scalariform thickening*).

Carefully draw one of these.

b. Other vessels (less numerous), having a continuous *spiral* thickening in their cell walls.

iii. Cut thin *transverse* sections of the wood of **Pinus.** Mount in glycerin, and examine with your highest power.

Observe :—

The *bordered pits*, lenticular-shaped spaces in the cell walls. These spaces communicate with the cavities of the adjacent cells, and are traversed by the *common cell wall* (usually deflected to one side).

iv. Cut thin *longitudinal* sections of the wood of **Pinus**, taking care that your sections are *radial* in direction.

Observe :—

The *bordered pits*, which appear as small dots on the surfaces of the elongated cells, like the dots on some of the vessels of the Cucurbita, but surrounded by a ring.

v. Draw these bordered pits as seen in longitudinal and transverse sections of the wood.

---

iv. Vegetable Cells—The Cell Wall.

(CONTINUED).

i. Cut thin transverse sections of the leaf of **Pinus**. Mount in glycerin, and examine with a high power.

Observe :—

a. The outermost layer of cells (epidermis) covered by an outer cuticularised cell wall, exhibiting *stratification.*

b. The cells immediately beneath the epidermis (*hypodermis*) whose walls are much thickened. In them, note :—

1. The thin *common cell wall*, or middle lamella.
2. The much thicker stratified thickening of the cell wall. It is equal on all sides, and presents a few straight canals (*pits*) passing through it and terminating at the common cell wall. The thickening is *uniform*, and gives to the cell wall a bright highly refractive appearance.
3. Granular cell contents.

ii. Cut very thin transverse sections of the leaf of **Ilex aquifolium** (holly), taking care that the sections pass through the large leaf veins on the under side of the leaf. Treat a section with Schultz' solution, and mount in water or in Schultz' solution. In the epidermis covering the veins on the under side of the leaf,

Observe :—

The cell wall made up of two zones, an inner one stained *blue*, and completely surrounding each cell; and an outer one extending continuously over all the cells (*cuticle*), and again distinguished into an inner layer stained *brown*, and an outer one *unstained*. In both zones note the stratification, and in the cuticle observe a few radiating lines at right angles to the surface (*striation*), due to different densities of the parts of the cell wall.

iii. Study and draw specimens of :—

a. Pollen grains of **Cichorium Intybus,** treated with spirit and mounted in glycerin.

Observe :—

External markings due to thickenings on the *exterior* of the cell walls.

b. Pollen grains of **Helianthus,** mounted in glycerin.

Observe :—

External spinose thickenings of the cell wall.

c. Cells from the rhizome of **Pteris,** obtained by maceration with Nitric Acid and Chlorate of Potash (which dissolves the common cell wall), and teased in a drop of glycerin.

Observe :—

1. Form of cells (polyhedral, or elongated and pointed at their extremities, or united together by perforation of their transverse septa, so as to form vessels).
2. The kind of thickening.
3. The pits (where present).
4 Layers of the cell wall.
5. Stratification (if present).

v. Vegetable Cells — Protoplasm — Movements.

i. Mount in water a piece of a filament of **Spirogyra.** Examine with a low power first, afterwards with a high one.

Observe :—

a. Somewhat elongated cells, placed end to end, so as to form a single row.

b. Cell wall between adjacent cells, common to each.

c. In each cell :—

1. *Cell wall.*
2. *Protoplasm*, the greater part of which forms a layer immediately beneath the cell wall (*primordial utricle*). From the primordial utricle, threads of protoplasm pass to some protoplasm placed near the centre of the cell. (These are sometimes difficult to make out.)
3. The spirally twisted band of *chlorophyll*, in the primordial utricle, with round starch grains, and globules of oil in it.
4. The *nucleus*, lying in the central mass of protoplasm (often indistinct).
5. The large *vacuole*, internal to the primordial utricle and traversed by the strands of protoplasm passing from it to the nucleus. The vacuole contains the colourless *cell sap.*

ii. Irrigate with Iodine ; or treat a filament with alcohol to dissolve the chlorophyll, and stain with carmine.

Observe :—

The staining of the protoplasm and nucleus ; cell walls remaining unstained.

If there are any starch grains in the chlorophyll band, these are stained *blue* with Iodine.

iii. Snip off with a pair of scissors the termination of a leaf of **Nitella.** Mount in water, and cover. Examine with high power. In one of the cells,

Observe :—

a. The outer layer of the primordial utricle, in which the regularly arranged chlorophyll bodies lie.

b. A white line, passing obliquely in the longitudinal direction of the cell, caused by the absence of chlorophyll.

c. The deeper layer of the primordial utricle (seen on focusing through the outer layer). It is slightly granular, and exhibits well marked *currents*, which pass in a longitudinal direction up one side of the white line and down the other (*rotation*). In the colourless line and in the outer layer of the primordial utricle, no movement is seen.

iv. Mount in water one of the stellate hairs on the calyx of the young flower of **Althœa Rosea.** In each cell,

Observe :—

Movement of the protoplasm from the primordial utricle along the strands connecting it with the central protoplasm near the nucleus, and back again. In some of the strands it is seen to flow in both directions, in others in one or other direction. (*circulation.*)

vi. Vegetable Cells—Starch—Chlorophyll.

i. Cut thin sections of the tuber of **Potato,** and mount in water. Examine with high power.

Observe :—

a. Cellulose cell walls, containing—

b. *Eccentrically oval starch grains.* In each, note

1. The *hilum* (eccentric).
2. The *layers* arranged around it.

c. In some starch grains, note *two* hila and two systems of layers, surrounded externally by layers as in the simple grains (*compound* starch grains).

d. Some grains have *several* hila.

ii Irrigate with *Iodine* solution.

Observe :—

The *blue* coloration assumed by the starch grains.

iii. Cut thin transverse sections of the seed of **Phaseolus** (kidney bean), previously soaked in water.

Observe :—

Concentrically oval starch grains.

Stain with Iodine.

In the seed of Phaseolus which has been dried, the starch grains often present the dark central radiating rupture described in iv.

iv. Treat some starch grains from **Potato** with Sulphuric Acid.

Observe :—

The appearance of a dark radiating rupture in the situation of the hilum (showing that this is the most watery part of the grain).

v. Mount in water a thin section of a softened seed of **Zea mais**.

Observe :—

a. The *cells*, containing—

b. Closely packed *lenticular* starch grains compressed into hexagonal shape.

vi. Observe the *lenticular* starch grains in the seed of **Triticum** (wheat).

Stain with Iodine.

vii. Study the starch grains of *Arrowroot*, *Barley*, &c., &c.

viii. Cut thin transverse sections of leaf of **Laurel**. Mount one in glycerin fresh, and a second in glycerin, after soaking for ten minutes in strong alcohol.

Observe :—

In *a*. The *chlorophyll corpuscles*, lying in the primordial utricle of the cells (*not* in the epidermal cells).

In *b*. *Yellowish coloured bodies* in situation of chlorophyll bodies in *a*. (The alcohol has dissolved the green colouring matter and left the protoplasmic ground untouched).

ix. Stain a section treated like specimen (*b*), with Iodine or with Carmine solution.

Observe :—

The protoplasmic matrix of the chlorophyll corpuscles stains like the rest of the protoplasm.

x. Study in the same way the chlorophyll bodies in the **Chara**; also those of **Spirogyra**.

vii. Vegetable Cells—Aleurone Grains, &c.

i. Cut thin sections of the seed of **Ricinus.** Mount one in strong glycerin, another in dilute glycerin, a third in alcohol after treatment with Sulphuric Acid, and stain a fourth in Iodine, mounting it in alcohol.

Observe :—

In *a.* The *aleurone grains,* containing (in some cases) *globoids.*

In *b.* The *crystalloids* in the aleurone grains.

In *c.* Empty spaces surrounded by a network of protoplasm (aleurone grains having been destroyed by Sulphuric Acid).

In *d.* The *aleurone* grains stained *yellow* or *yellowish-brown.*

ii. Mount some thin sections of the seed of **Ricinus** in alcohol, and then irrigate with a saturated solution of common salt.

Observe :—

The solubility of the aleurone grains.

iii. Mount similar sections in alcohol and irrigate with potash solution.

Observe :—

The solubility of the aleurone grains and the crystalloids.

iv. Cut thin sections of the **Brazil Nut.** Mount in saturated solution of salt without previously treating with alcohol.

Observe :—

The aleurone grains have been dissolved, globoids insoluble.

v. Mount similar sections in alcohol.

Observe :—

a. The aleurone grains, in their typical form.

b. The large oil globules.

c. Protoplasm and cell walls of the cells.

vi. Test the solubility of the globoids, left in specimen iv, with dilute Acetic Acid; they dissolve. Globoids are composed of a double phosphate of lime and magnesia.

vii. Examine and draw the following :—

a. *Raphides* (Calcium Oxalate), consisting of needle-shaped crystals, from the leaf of **Hyacinthus.**

b. *Octahedral* crystals of Oxalate of Lime, from the petiole of **Begonia.**

c. *Cystoliths.* These are not, properly speaking, contents of cells, but are made up of clusters of crystals of Carbonate of Lime deposited in ingrowths of the cell walls. They are well seen in sections of the leaf of **Ficus elastica,** where they are found as irregular globular bodies suspended by a sort of stalk, in the cells just beneath the upper layer of epidermis.

viii. Vegetable Tissues.

i. Cut longitudinal sections through the apical region of the rhizome of **Pteris.** Mount in glycerin and examine with a low power.

Observe :—

a. Near the apex, a large number of small closely packed rounded or polyhedral cells. In each cell, notice the thin cell wall and the protoplasmic contents. All the cells in this part are alike, and are generating cells (*meristem*).

b. Trace the cells which form the outermost layer downwards from the apex. They change their form gradually as you proceed from the apex, becoming more elongated and flattened (*dermatogen* passing into *epidermis*).

c. Trace also the cells of the inner layers downwards; some of them are seen to gradually become elongated, spindle shaped, and acquire thicker cell walls (*prosenchyma*). Others become elongated and fuse together, and acquire scalariform or spiral thickenings in their walls (*vessels*). Others retain their thin cell walls, but become larger (*parenchyma*). All these varieties of cells are *permanent tissue.*

ii. Cut longitudinal sections of the rhizome of **Pteris.** Mount in glycerin and examine first with a low, and then with a high power.

Observe :—

a. The general ground tissue, made up of cells whose diameters are about equal in each direction; they have thin cell walls, and contain protoplasm and starch grains. In the cell wall common to the adjacent cells, note spaces here and there (*intercellular spaces*). These cells constitute the *form* of tissue called *parenchyma.*

b. In the ground tissue, are masses of cells of brown colour, which are seen to be elongated and fusiform. They overlap each other at their extremities, and no intercellular spaces are seen. They constitute the *form* of tissue called *prosenchyma.* They have their cell walls much thickened and hardened, and hence constitute that variety of prosenchyma called the *sclerenchymatous.*

c. In the ground tissue also are masses of cells of yellowish colour, distinguishable into several layers (*fibro-vascular bundles*). In them, note the elongated cells, with scalariform thickening in their walls and communicating with each other at their extremities. These are examples of *vascular tissue*, *vessels* or *tracheæ.*

iii. Observe the same forms of tissue in transverse sections of the rhizome.

iv. Cut longitudinal radial sections of the wood of the stem of **Pinus.** Examine with a high power, in glycerin.

Observe :—

a. The elongated cells of prosenchymatous form with thick walls, and presenting—

b. *Bordered pits* (page 13).

c. In the place of bordered pits, at certain parts of the fibres, are seen groups of large quadrilateral or rounded areas in the walls of the fibres. These are in the position of the medullary rays (see *Pinus*).

Such cells are called *tracheïdes.*

ix. Varieties of Parenchyma.

i. Study the typical parenchyma in sections of the rhizome of **Pteris**, or of the pith of **Helianthus** or **Elder**.

Observe :—

Thin-walled cells, of about equal diameters in both directions, and having triangular intercellular spaces in the midst of the common cell walls of adjacent cells.

ii. Cut thin transverse sections of the petiole of **Begonia** or of **Helianthus**.

Observe :—

a. The outermost layer of tissue (*epidermis*).

b. Immediately beneath the epidermis, note some parenchymatous cells, the angles of the cells of which present triangular bead-like thickenings in their cell walls (*collenchyma*).

iii. Cut thin transverse sections of the leaf of **Laurel**, and mount in glycerin.

Observe :—

a. The *pallisade* parenchyma, consisting of cells arranged in a prismatic manner, just beneath the upper layer of epidermis and containing chlorophyll.

b. *Spongy* parenchyma, near the lower layer of epidermis, and consisting of rounded loosely arranged cells, between which, are large intercellular spaces. The cells contain chlorophyll corpuscles.

iv. Cut thin transverse sections of the leaf of **Pinus**, mounting in glycerin.

Observe :—

a Thick-walled cells just beneath the epidermis (*sclerenchymatous* parenchyma). They present a highly refractive, bright appearance, and have little cell contents.

b. Beneath this layer, some thin-walled cells, whose walls are folded so as to form projections into the interior of the cells (*folded* parenchyma). The cells have very distinct protoplasm, and small oval chlorophyll corpuscles.

v. In sections of the stem of **Juncus,**

Observe :—

Stellate parenchyma, consisting of star-shaped cells united together by the rays of the stars, and having large triangular or quadrilateral intercellular spaces.

vi. Carefully draw all these varieties of parenchyma, taking care to draw the cells with a *double contour* to the cell walls, and to correctly draw the intercellular spaces where present.

X. Systems of Tissues — Epidermal Tissue.

i. Strip off a piece of epidermis from the under surface of the leaf of **Laurel.** Soak for a few minutes in spirit, and mount in glycerin. Examine with a high power.

Observe :—

a. The ordinary *epidermal* cells, forming a kind of pavement, each cell with a somewhat sinuous outline, and a definite bright cell wall with a double contour.

b. Absence of chlorophyll in the epidermal cells.

c. The *stomata*—elliptical openings, scattered here and there, between the epidermal cells.

d. The *guard cells*—two kidney-shaped cells which surround the stomata, and are different in appearance from the ordinary epidermal cells. On careful focusing, it is seen that they are on a different level to the ordinary epidermal cells, being depressed below the surface.

e. Presence of granular contents in the guard-cells.

ii. Cut thin transverse sections of the leaf of **Dianthus caryophyllus.** Mount in glycerin. Examine with high power, studying only the surfaces of the sections.

Observe :—

a. The *cuticle*, or distinct outer thickened cell wall of epidermal cells, presenting stratification.

b. The *epidermal cells*, forming a single layer, distinct from the fundamental tissue beneath. Note the absence of chlorophyll in the epidermal cells, and its presence in the cells of the fundamental tissue.

c. The *stomata*, appearing as distinct openings in the surface and traceable into an intercellular space in the fundamental tissue.

d. The *guard cells*—two cells depressed below the surface of the other epidermal cells and bounding each stoma. These two cells contain chlorophyll and starch. Note their *form*, their *cell walls* and *contents*.

iii. Cut thin transverse sections of the stem of **Geranium.** Mount in glycerin, and examine the surfaces of the sections.

Study :—

a. The *epidermal cells*, distinct from the parenchymatous cells beneath.

b. The *hairs*. Note that each hair arises from the epidermis, and has no deeper attachment. Some of them are elongated, pointed at their extremities, and have thick cell walls; others are terminated by large globular cells with dark granular contents; others are short, small, and globular at their extremities, and dark in colour (*glandular hairs*).

iv. Study the various stages in the development of stomata and guard cells, in the epidermis of the young leaf of **Hyacinthus,** by stripping off the distinct epidermal layer, and mounting it in glycerin.

Observe :—

a. The *form* of the epidermal cells—large, elongated, with definite angles, quadrilateral.

b. *Stage i.*—Certain square cells which have been divided off from the longer quadrilateral cells, and lie in rows interrupted by the ordinary epidermal cells.

c. *Stage ii.*—The division of these square cells by a thin partition wall in each, formed longitudinally.

d. *Stage iii.*—A central thickening of this thin partition wall.

e. *Stage iv.*—Formation of a longitudinal slit in the midst of this thickened part of the partition. This slit extends completely through the depth of the partition, and forms the stoma.

f. *Stage v.*—Rounding off of the two cells, to form the kidney-shaped *guard cells*.

xi. Fundamental Tissue.

i. Recapitulate the varieties of parenchyma described at page 21.

ii. Make thin transverse sections of the petiole of **Begonia**, mount in glycerin, and examine the fundamental tissue immediately beneath the epidermis (Hypoderma).

Observe :—

That it consists of *collenchyma*, and appears different from the rest of the fundamental tissue (the cells being smaller).

iii. Make thin transverse sections of the leaf of **Pinus**, mount in glycerin, and examine the Hypoderma.

Observe :—

That it is *sclerenchymatous*, and that the cells have extremely thick walls.

iv. Make thin transverse sections of the stem of **Helianthus** or of **Ricinus**. Examine the outer surfaces of the fibro-vascular bundles, and the general fundamental tissue.

Observe :—

a. That the general fundamental tissue is made up of large parenchymatous cells, with thin cell walls, and having intercellular spaces.

b. The *bundle-sheath* or *endodermis*, consisting of a single layer of small cells belonging to the fundamental tissue, lying outside the ring of fibro-vascular bundles and forming a common sheath for all the fibro-vascular bundles. It does not surround each separate bundle. The cells are much smaller than the rest of the fundamental tissue, which is seen to consist of ordinary thin-walled parenchyma; and they contain small starch-grains. It is sometimes called the *starch-ring*.

The radial walls of the cells of the bundle-sheath are cuticularised, and present a characteristic appearance of a *black dot*.

v. Make thin transverse sections of the root of **Vicia Faba**, mount in glycerin, and study the *endodermis* which lies outside the pericambium of the fibro-vascular bundles, and is a portion of the fundamental tissue.

vi. Make thin transverse sections of the stem of **Juncus.** Examine the tissue around the fibro-vascular bundles, in the peripheral parts of the sections.

Observe :—

That each fibro-vascular bundle (which is *closed*) is completely surrounded by several layers of cells, which have a bright appearance, and whose walls are very thick and sclerenchymatous. This is the so-called *external sheath.* It is quite different from the endodermis of Ricinus.

vii. Examine the dark brown sclerenchymatous ring of prosenchyma belonging to the fundamental tissue, in transverse and longitudinal sections of the rhizome of **Pteris.** Also examine some of the cells obtained from this layer by maceration in Schultz' macerating solution.

Observe :—

a. That the cells are *prosenchymatous* in form.

b. Their walls are much thickened and stratified.

c. There are pits in the thickened wall.

d. In addition to the common cell wall, there are two other layers of thickening, special to each cell.

viii. Cut thin transverse sections of the young, and also of the older stem of **Hedera Helix.** Examine with a high power.

Observe :—

a. In the cortical fundamental tissue and in the soft bast, a few dark coloured cells surrounding an intercellular space. In very young cases, the intercellular space is absent, and groups of four dark coloured cells are seen.

b. In older sections, observe that the coloured cells are small and numerous, and that the space is larger. The space represents the transverse section of a *resin duct.* It is formed by separation of cells, and is therefore said to be of *schizogenous* origin ; and as the duct enlarges the surrounding cells undergo division.

ix. Observe similar resin ducts in the leaf of **Pinus,** seen on making transverse sections, and examining in glycerin with a high power.

x. Cut thin longitudinal sections of the root of **Taraxacum.** Stain in logwood or carmine, clear in potash and mount in glycerin.

Observe :—

The *laticiferous vessels*, consisting of long branched rows of cells, the walls separating which, have been absorbed. These lie in the phloëm or cortex, and their contents are darker than those of the other cells.

xi. Cut thin longitudinal sections of the stem of **Euphorbia.**

Observe :—

The *laticiferous cells*, consisting of much branched cells having thick walls and dark granular contents, amongst which are found peculiar starch grains of a dumb-bell form. They lie in the cortical fundamental tissue.

xii. Systems of Tissues—Fibro-Vascular Bundles.

i. Cut transverse sections of the rhizome of **Pteris aquilina.** Mount in glycerin, and examine with a low power.

Observe :—

a. The general *ground tissue*, made up of thin-walled colourless cells containing starch grains. Just beneath the epidermis, the cells of the ground tissue are of dark brown colour.

b. The *sclerenchyma*, forming a dark-coloured horse-shoe shaped mass of cells with thick walls, lying in the general ground tissue.

These two form the *fundamental tissue.*

c. The *epidermis.*

d. The *fibro-vascular bundles*, consisting of isolated masses of cells of a yellowish colour lying in the fundamental tissue. They have no definite arrangement, and have a more or less elliptical form.

ii. Examine with a high power, one of the fibro-vascular bundles, and make out the following layers from without inwards :—

a. The *bundle sheath*, consisting of a single layer of cells of the *fundamental tissue*, usually of a dark brown colour.

b. The *phloëm*, a stratum of cells consisting of several layers, passing completely round the bundle, inside the bundle sheath. The cells are thin walled, some of them small, others larger.

c. The *xylem*, occupying the whole of the central part of the bundle, and consisting chiefly of large polygonal cells with thick walls, and of smaller cells near the central parts of the bundle.

This arrangement of the phloëm as a complete layer surrounding the xylem is known as the *concentric* arrangement.

iii. Stain a section in Schultz' solution, and mount in water.

Observe :—

a. The general ground substance has its cell walls stained *blue* (cellulose).

b. The cell walls of the bundle sheath become *browner* than when unstained (cutin).

c. Those of the phloëm are stained *blue.*

d. Those of the xylem are stained *yellow* (lignin).

e. The cell contents stain *brown*, except :—

f. The starch-grains, which stain *blue.*

iv. Examine the phloëm and xylem more carefully, making out in order from without inwards :—

a. The *bast sheath*, a single layer of thin-walled cells, containing protoplasm and starch granules, and lying just inside the bundle sheath.

b. The layer of small cells, consisting of *bast fibres*, having very thick walls and small cell cavities, intermixed with *bast parenchyma*, consisting of thin-walled cells containing protoplasm.

c. The layer of larger thin-walled cells more internal to *b* and just external to the very large cells of the xylem. These are the *bast vessels* or *sieve tubes.* They contain protoplasm.

d. The large cells of the xylem, having thick cell walls, more especially at their margins. These are *scalariform vessels.* They have no cell contents.

e. Smaller cells near the centre of the bundle, thin walled and containing starch grains. These constitute the *xylem parenchyma*, lying in which, are one or two *spiral vessels* which are the oldest elements of the xylem, and may therefore be called *protoxylem.*

v. Cut thin longitudinal sections through a fibro-vascular bundle in **Pteris**, and examine with a high power in glycerin, making out the layers of cells described under iv.

The bundle sheath and the bast-sheath are seen to consist of *parenchymatous* cells.

The bast fibres are seen to be elongated and *prosenchymatous*, and to have thickened walls.

The *bast vessels* are long, have thin walls, and upon their longitudinal walls present numerous triangular areas having a dotted appearance, due to perforations in these positions (*sieve plates*).

The *scalariform* vessels consist of long cells, overlapping at their extremities and having regular transverse thickenings in their walls. (*Vide* page 12.)

The *xylem parenchyma* has the appearance of ordinary parenchymatous tissue, and the spiral vessel, which may be cut in the section, has the ordinary structure of a spiral vessel.

xiii. Systems of Tissues—Fibro-Vascular Bundles (Continued).

i. Cut thin transverse sections of the young stem of **Helianthus** (Sunflower), and examine with a low power in glycerin.

Observe :—

a. *Epidermis.*

b. *Fundamental tissue* of parenchymatous cells.

c. *Fibro-vascular bundles.* These are masses of cells distinctly marked off from the fundamental tissue and lying imbedded in it. They form a *ring*, interrupted by strands of fundamental tissue which pass between the bundles. The ring of fibro-vascular bundles divides the fundamental tissue into two parts—the central mass called the *medulla*, and the peripheral part, lying between the fibro-vascular bundles and the epidermis, called the *cortex.* The strands of fundamental tissue lying between the bundles are the *primary medullary rays.*

This arrangement of tissues is characteristic of *Dicotyledons.*

d. In each bundle, make out three distinct parts, viz. :—(1) A mass of dark coloured cells lying most internally, and consisting of several large cells (*vessels* in transverse section) with numerous smaller cells between them (*wood fibres* in transverse section). All these cells have thick cell walls. They constitute the **xylem** of the bundles. (2) Most externally in each bundle, is another mass of tissue, consisting almost entirely of small cells. Those nearest the exterior have very thick walls, and have a bright refractive appearance (phloëm fibres). Internal to these, are several layers of thin-walled cells, mostly small, with a few larger ones scattered amongst them. All these form the *soft bast.* The soft bast and the phloëm fibres constitute the **phloëm** of the bundles. (3) Between the phloëm and the xylem, there lie several layers of very thin-walled cells, which are small and quadrilateral, their longer walls being placed tangentially. This mass of tissue, which appears quite different from the phloëm and xylem, is a *meristem*, or generating tissue. It is known as the **cambium.** From it, new xylem and phloëm are in process of formation. The oldest parts of the xylem and phloëm are those *furthest* removed from the cambium. (Cf. Roots.)

Fibro-vascular bundles having a layer of cambium are said to be *open.* This is very characteristic of Dicotyledonous plants.

e. Outside the bundles, can be seen a single layer of cells *of the fundamental tissue*, different from the rest and containing starch grains. This layer surrounds *all* the bundles, and is called the *bundle-sheath.*

Make a drawing, showing all the above parts.

ii. Stain a thin section in Schultz' solution, and mount in water.

Observe :—

a. *Fundamental tissue* has its cell walls stained *blue.*

b. *Hard bast* stained *brown* or *yellow.*

c. *Soft bast* stained *blue.*

d. *Cambium* stained *blue.*

e. *Xylem* stained *yellow* or *brownish.*

iii. Examine your thinnest section with the high power, and make out the various parts of the bundles more in detail.

Observe :—

In the **phloëm**—

a. The thick-walled *phloëm fibres.* Draw a few.

b. The thin-walled *phloëm cells*, amongst which are scattered :—

c. The larger thin-walled *phloëm vessels* or *sieve tubes.*

In the **xylem**—

a. The large thick-walled *wood vessels*—(*spiral vessels* most internally in the oldest parts of the xylem, *pitted vessels* more externally).

b. The small thick-walled *wood fibres*, scattered amongst the vessels.

Draw them; also draw the thin-walled *cambium cells.*

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xiv. Systems of Tissues—Fibro-Vascular Bundles (CONTINUED).

i. Cut thin longitudinal *radial* sections of the stem of **Helianthus.** Mount in glycerin. Examine with a low and then with a high power. Look for a section which has passed through a fibro-vascular bundle.

Observe :—

a. The *xylem*, consisting of *vessels*, *wood fibres*, and *wood cells.* In the most internal parts of the xylem, make out the vessels whose walls have a continuous spiral thickening. Focus carefully, and make out that the spiral appearance is due to a continuous band of thickening which passes round and round the vessel. Note, that the spiral vessels vary in size. More externally, make out one or two vessels whose walls appear to be dotted over with clear looking spots. Where the wall of one of these vessels happens to be in section, make out that the dotted appearance is really due to pits in the cell wall, left unthickened as the rest of the wall became thickened.

Amongst the vessels, make out a few elongated prosenchymatous cells with thick walls, especially seen in the external parts of the xylem. These are the *wood fibres* which in transverse section appear as small rounded cells (page 29).

Here and there, a few thin-walled somewhat elongated cells may be seen amongst the xylem vessels. These are the *xylem parenchyma.*

b. The *cambium*, consisting of thin-walled flattened elongated cells, with clear contents, lying external to the xylem.

c. The *phloëm*, consisting of *phloëm vessels*, *fibres*, and *cells*. The vessels are the largest of the elements of the phloëm, and are called *sieve tubes.* They are so named because their continuity is interrupted by transversely or obliquely placed partitions, perforated by minute canals so as to resemble a sieve. These are named the *sieve plates.* They are the original transverse walls by which the cells composing the sieve tubes were originally separated from each other. The perforations in them establish a communication between the adjacent cells of the vessel. Where the sieve plates occur, the vessels appear to be swollen.

The granular protoplasmic contents of the sieve tubes can be seen.

Amongst the sieve tubes, observe a few small thin-walled cells which form the *phloëm parenchyma.*

Outside these two kinds of cells which form the *soft* bast, are to be seen several layers of prosenchymatous thick-walled cells. These form the *hard bast* or *bast fibres.*

d. Outside the bundle, note the *bundle sheath* or *starch-ring.*

Make a drawing showing all these points.

ii. Pick out the section which shows sieve tubes best, and stain it in iodine solution, or better, with methyl violet or eosin, and examine with a high power.

Observe :—

The stained protoplasm in the sieve tubes; and endeavour to make out the continuity of the stained protoplasm from cell to cell, through the perforations in the sieve plate.

iii. Carefully compare your longitudinal sections with the transverse ones already made (page 28).

xv. Systems of Tissues—Fibro-Vascular Bundles (Continued).

i. Cut transverse sections of the stem of **Cucurbita.** Examine in glycerin with a low power.

Observe :—

a. The *fibro-vascular bundles.* In each bundle, will be seen four kinds of tissue—the most external is *phloëm,* containing the usual elements. The next layer of tissue is the *cambium ;* the third is *xylem,* consisting of the usual elements, with very large dotted, annular, and spiral vessels. More internally than the xylem, is seen a mass of tissue, consisting of small thin-walled cells with granular contents, and a few large cells. It, in fact, has the appearance and structure of phloëm ; and is a *second mass of phloëm.* This arrangement is not common.

b. *Tüllen.* This is the term applied to an appearance which is sometimes seen in the large dotted vessels of the xylem. They appear to be filled with numerous rounded cells. If your section is thin enough, the nature of this appearance will become clear. Here and there, it will be seen that the rounded cells lying inside the vessels are the thin cell walls of adjacent cells, which, by alteration of pressure relations, have been pushed through the pits in the walls of the vessels.

ii. Make the second mass of phloëm more distinct, by staining a thin section in Schultz' solution, and mounting in water.

Observe :—

Blue coloration of the two phloëm masses, and *yellow* coloration of the xylem.

iii. In longitudinal radial sections of the stem of **Cucurbita** or of **Vitis,** the structure and nature of sieve tubes of the phloëm can be well seen, particularly in thin sections stained with eosin, or methyl violet, or carmine, cleared in clove oil and mounted in balsam. (*Vide* Helianthus.)

iv. Cut thin transverse sections of the stem of **Lupinus.** Examine in glycerin, with a low and also with a high power.

Observe :—

a. *Interfascicular cambium.* This is a structure not seen in very young stems, and is only formed in those stems which have open bundles, and which increase in thickness by means of a cambium-ring. It is a meristem, which is formed in the fundamental tissue of the primary medullary rays after the fibro-vascular bundles have been developed. As seen in your sections, it consists of thin-walled cells with their long walls placed tangentially, and in general appearance exactly like the cambium of the fibro-vascular bundles.

b. The *cambium ring.* The interfascicular cambium is continuous with the cambium of the bundles, so that a *complete ring* of meristem is formed, consisting of fascicular and interfascicular cambium, alternating with each other. By the division of cells which takes place in this tissue, new or secondary xylem and phloëm are produced, forming *continuous rings.*

This is characteristic of the stems of *Dicotyledons.*

v. Make drawings.

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xvi. Systems of Tissues—Fibro-Vascular Bundles (CONTINUED.)

i. Cut thin transverse sections of the stem of **Asparagus.** Examine with a low power in glycerin.

Observe :—

a. The *fundamental tissue.*

b. The *fibro-vascular bundles.*

c. The *absence* of any definite arrangement of the fibro-vascular bundles (characteristic of Monocotyledons).

d. The bundles in the *centre* of the stem are *larger* than those in the periphery. This is owing to the fact, that the fibro-vascular bundles as they pass down the stem gradually approach the surface of the stem, and gradually become smaller.

e. A ring of tissue in the peripheral part of the stem outside the fibro-vascular bundles. This is a ring of prosenchymatous tissue. It is *not* a meristem, and is *in no way comparable* to the cambium ring of Dicotyledons. *Draw* a section.

ii. Examine a fibro-vascular bundle with a high power.

Observe :—

a. The *xylem*, placed internally with respect to the surface of the stem. It has somewhat the form of a horse-shoe partially surrounding the phloëm. Most internally, it consists of small cells and spiral vessels in section (*protoxylem*) more externally of large vessels, which are particularly large where it encloses the phloëm laterally.

b. The *phloëm*, consisting of small-celled tissue with a few sieve tubes, lying externally and between the two lateral parts of the xylem. In the external parts of the phloëm, are some *phloëm fibres*.

c. The *entire absence* of cambium. Such a fibro-vascular bundle as this is said to be *closed*, on account of the absence of cambium and the impossibility of further growth after the bundle is fully formed (characteristic of Monocotyledons). The arrangement of the parts of a fibro-vascular bundle as found in Mono- and Dicotyledonous stems, viz., phloëm externally and xylem internally along the same radius, is called *collateral* (Cf. *Pteris* and *roots*).

iii. Stain a section in Schultz' solution, and mount in water.

Observe :—

a. *Blue* coloration of cell walls of the fundamental tissue.

b. *Blue* coloration of the phloëm cell walls.

c. *Yellow* coloration of the xylem cell walls.

iv. Cut thin longitudinal sections of stem of **Asparagus**, and make out the characters of the vessels and cells composing the xylem and phloëm.

v. Make drawings.

xvii. Fibro-Vascular System in Roots.

i. Cut thin transverse sections of the young primary root of **Vicia Faba** or **Phaseolus**, or of **Helianthus** soon after germination of the seed. Examine in glycerin, with a low and high power.

Observe :—

a. The *epidermis.*

b. The general *fundamental tissue.*

c. The axial *fibro-vascular cylinder.* Surrounding the fibro-vascular cylinder, note a single layer of cells (the *endodermis*). Inside this, there lies a second layer of cells of parenchymatous form called the *pericambium* or *rhizogenetic layer.* From it, the secondary roots take origin, as endogenous developments. Make out the four radiating *xylem-masses*, having their apices placed against the pericambium, and becoming broader internally. In the middle of this xylem-cylinder may be seen a large mass of parenchymatous cells forming the *medulla.* Alternating with the four xylem-masses, and lying outside them but inside the pericambium, are four *phloëm masses.* Between the phloëm and xylem masses, note a few layers of small parenchymatous cells, which form the *conjunctive tissue* of the fibro-vascular cylinder. Outside the rhizogenetic layer is the *endodermis* or *bundle sheath.*

This arrangement of the parts of a fibro-vascular bundle is called the *radial* arrangement (Cf. *concentric* and *collateral*), and is very characteristic of roots in general.

The number of xylem and phloëm rays in a radial fibro-vascular bundle may be very various. When few, the bundle is said to be *oligarch.* When many, *polyarch.* The former is the general rule amongst Dicotyledons, the latter amongst Monocotyledons. The most common amongst Dicotyledons are the *diarch* or *tetrarch bundles.*

ii. Examine a thin section carefully with a high power.

Make out :—

a. The *xylem.* It consists of small vessels in its peripheral parts, and larger ones more internally. The peripheral parts are the *oldest*, having been first formed, and consist of reticulated or spiral vessels. The internal parts are made up of large reticulated or pitted vessels.

b. The *phloëm*, consisting chiefly of a mass of small thick walled phloëm-fibres with one or two sieve tubes lying internal to them.

The secondary roots arise from the pericambium at the points or apices of the xylem masses.

iii. Cut thin transverse sections of the secondary roots of **Hyacinthus.** Mount in glycerin and examine with a medium power.

Observe :—

a. The same general structure as in Phaseolus.

b. *Polyarch* fibro-vascular cylinder.

c. *Phloëm* less conspicuous.

d. *Central pith*, less marked or absent.

iv. Cut thin transverse sections of an older root of **Phaseolus.**

Observe :—

a. A *cambium* ring, not complete, and formed only in the same radii as the primary phloëm masses.

b. *Secondary xylem*, which has been produced from it by secondary growth. It alternates with the primary xylem masses.

c. Central *medulla* of fundamental tissue.

The secondary increase in thickness which takes place occurs by the formation of a meristem or *cambium* between xylem and phloëm and the subsequent production of secondary xylem, as in the Dicotyledonous stem. This does not occur in Monocotyledons.

xviii. Fibro-Vascular System in an Older Dicotyledonous Stem.

i. Cut thin transverse sections of an old stem of **Vicia Faba.** Examine in glycerin with a low power.

Observe :—

a. The *pith cavity*, with the remains of the pith around it.

b. The cortical part of the fundamental tissue, covered externally by epidermis.

c. Between *a* and *b*, the *fibro-vascular system*, consisting of :—

1. The *primary xylem*, appearing as projections inwards from the general fibro-vascular ring.
2. The *secondary xylem*, consisting of a continuous ring of tissue external to the masses of primary xylem.
3. The *cambium ring* of thin-walled cells, external to the secondary xylem. By division of the cells of this, the secondary xylem has been produced.
4. *Secondary phloëm*, forming a narrow ring outside the cambium.
5. The *primary phloëm* masses, outside the secondary phloëm.

ii. Cut transverse sections of a one-year-old stem of **Pinus** (which, though not a Dicotyledon, increases in thickness like one). Examine with a low power, in glycerin.

Observe :—

a. The *pith.*

b. The *cortex.*

c. The *cambium ring.*

d. The *phloëm*, made up of primary phloëm masses externally, and layers of secondary phloëm adjoining the cambium.

e. The *wood* or xylem, consisting of the primary xylem adjoining the pith, and forming the so-called *medullary sheath*, and the secondary xylem, constituting the greater part of the wood. Direct your attention specially to this, and note that it presents a radiating appearance due to the arrangement of the cells composing it. Make out that the greater number of the cells in it are large, and have thickened walls; whilst numerous narrow bands of cells, much smaller and with thin walls, are seen. These radiate from the centre towards the periphery, and constitute the *secondary medullary rays.*

iii. Examine your thinnest section with a high power.

Observe :—

a. The *wood fibres* of the secondary xylem. They appear in section to be quadrilateral, and their cell walls can be seen to be made up of two layers. (*a*) The *common cell wall ;* and (*b*) the *thickened portion* special to each fibre. Note the *bordered pits*, appearing as lenticular spaces in the radial cell walls.

b. The *secondary medullary rays*, each consisting of a single row of small thin-walled cells. These rows of cells are bounded on both sides by wood fibres. Note that the walls of the wood fibres adjacent to the medullary rays are unthickened, whilst their other three walls are thickened. Trace one of the medullary rays throughout its whole extent.

iv. Make drawings.

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xix. Cork—Lenticels.

i. Cut thin transverse sections of the one-year-old stem of **Ribes** (Currant), mount in glycerin. Examine the thinnest part of your sections with a high power.

Observe :—

a. Shreds of *epidermis* at the surface of the section, together with a few parenchymatous cells of the cortical fundamental tissue.

b. Beneath this, but outside the fibro-vascular region, lies the cork tissue or *periderm*, consisting of quadrilateral cells whose cell walls have become cuticularised, and which have lost their protoplasmic contents.

c. At the deeper parts of the periderm, are seen one or two layers of cells of the same shape but narrower, and having thinner cell walls and finely granular protoplasm. These are meristematic cells, and form the *cork cambium* or *phellogen.*

d. Beneath the phellogen may sometimes be seen other cells, which have been produced by the phellogen, and which form the *phelloderm.*

e. Beneath this, lies the remaining portion of the primary cortical fundamental tissue.

ii. Stain a section with Schultz' solution, and mount in water.

Observe :—

a. Yellow coloration of the periderm.

b. Blue coloration of the phellogen.

iii. Cut thin transverse sections of a present year's shoot of **Sambucus Nigra** (Elder). Mount in glycerin. Examine the surfaces of your thinnest sections with a moderately high power.

Observe :—

The *lenticels*, which appear as somewhat raised spots on the surface of the stem. At these spots, the epidermis appears to be broken away, and the space to be filled with rounded loosely arranged cells separated by intercellular spaces. Beneath these loosely arranged cells, is a layer of phellogen continuous with the phellogen ring. In fact, at these spots the cork cambium, instead of producing ordinary cork cells, has formed this loosely arranged tissue. The lenticels perform the functions of stomata after these structures have disappeared during the growth of the stem. Sometimes the loosely arranged tissue of the lenticels is seen underneath the stomata of the epidermis.

iv. If the surface of a young twig of Elder be examined with the naked eye, or with a pocket lens, the lenticels may be seen as whitish or yellowish areas on the surface.

v. Make drawings.

XX. Apices of Stems.

i. Cut off the apex of the stem of **Chara**. Carefully dissect it with needles in a drop of glycerin, and then gently press it out with a cover slip, and examine with a moderately high power.

Observe :—

a. The *apical cell*, in shape hemispherical with the rounded surface outwards and the flat surface adjacent to the cell below. Note, its protoplasm and nucleus (sometimes *two* nuclei). It divides transversely by a division plane parallel to its base.

b. The *cell beneath the apical cell.* It may be a nodal or an internodal cell. By working downwards from the apex, it will be seen that nodal and internodal cells alternate.

c. The *internodal cells* are seen, as you pass down, to gradually enlarge, develop vacuoles, and eventually become the central cell of an internode. *They never divide.*

d. The *nodal cells.* These do not increase in size, but they undergo repeated division, and give rise to the cells of *the nodal regions; the leaves*, which are seen to arise as outgrowths from the nodal regions; the *cortical cells* of the internodes; and *branches*, which arise as outgrowths from the nodal regions in the axils of the leaves.

ii. Cut thin longitudinal sections of the apex of the rhizome of **Pteris**. Examine with a low power.

Observe :—

a. A depression in the middle of the rounded apex.

b. The brown coloured trichomes which cover the apical region.

c. At the extreme apex, if you are fortunate, you may see one cell, of wedge-like form with its apex directed downwards. This is the apical cell, by division of which all the other cells are formed.

d. Usually, you will see a mass, several layers in thickness, of small rounded cells with thin walls occupying the extreme apex of your section. These are indifferent cells of the *primary meristem* which have been formed by the apical cell.

e. Tracing the primary meristematic tissue downwards, you find that it undergoes a differentiation into definite parts.

1. A single layer of cells at the surface, which traced downwards becomes continuous with the epidermis. This is the *dermatogen.*
2. A mass of meristematic cells occupying the whole of the central part. This mass is of darker appearance than the rest of the cells, and the layers of cells composing it seem to converge above to a rounded summit, in the middle line beneath the indifferent cells at the extreme apex. Traced downwards, some of these cells become continuous with the fibro-vascular bundles, and others with the sclerenchyma ring and the central fundamental tissue. They may be called the *plerome.*
3. Between the dermatogen and plerome, there lies a mass of cells which remain thin-walled and clear, and can be traced downwards into continuity with the fundamental tissue of the peripheral region. This layer of meristem may be called the *periblem.*

iii. *Carefully draw the two apical regions*, noting carefully the differences between them.

iv. Cut thin longitudinal sections through the apical region of **Helianthus** before the development of the flower.

Observe :—

a. The expanded growing point.

b. The leaves at the periphery.

c. Absence of a *single apical cell.*

d. Differentiation of the primary meristem into *dermatogen, periblem and plerome.* This is the general rule amongst *Phanerogams.*

xxi. Apices of Roots.

i. Soak some "seeds" of **Zea mais** in water, make out the position of the embryo, and cut thin sections passing longitudinally through it. Examine with a low and high power.

Observe :—

The apex of the young stem or *plumule.*

The large single *cotyledon.*

The apex of the young root or *radicle.* Make out the following layers of meristematic cells :—

a. The *root-cap* or *calyptra* lies most externally at the extreme tip of the root and outside the growing apex. It consists of many layers of cells, the most external being oval in shape and loosely held together. These are the oldest cells of the cap and are continuous with a special lower part of the cotyledon, known as the *scutellum.* More internally, there lie several layers of compressed polygonal smaller cells, forming the younger tissue of the root-cap.

b. The *calyptrogen* layer, consisting of small generating cells lying outside the true growing apex and from which the calyptra is developed.

Trace the cells of the root-cap laterally and gradually tapering off as you pass up the root. They are sharply marked off from the deeper layers.

c. The outline of the true growing apex, marking the cells of the root from the calyptra. Note the cap-shaped depression in the middle line of the extreme apex.

d. In the region of the cap-shaped depression, a single layer of cells, the common *initial layer* for the next two masses of cells of the apical region.

e. The *dermatogen*, forming a single layer of compressed quadrilateral cells at the surface near the apex. Traced backwards, it becomes continuous with the epidermis; and towards the apex, with the single initial layer of cells which is common to it and the next mass of cells.

f. The *periblem*, consisting of several layers of thin-walled colourless cells, lying beneath the dermatogen and between it and a darker coloured central cylinder of cells, occupying the central parts of the root. Traced toward the apex, the number of layers of cells composing it gradually diminishes, till it becomes continuous with the single initial layer at the extreme summit. The periblem is usually sharply marked off from the cells more internal to it. Traced backwards, the periblem passes into the cortical fundamental tissue.

g. The *plerome*, consisting of all the central layers of cells of the apical region. It is usually of darker appearance than the periblem, and terminates in a rounded extremity just beneath the initial layer of cells for dermatogen and periblem at the cup-like apex.

h. The *growing point* can easily be recognised with a low power, by tracing the various layers as they converge towards it.

ii. Cut thin longitudinal sections of the primary radicle seen in the seed of **Phaseolus** (Kidney Bean). Examine with low and high powers.

Observe :—

a. The *root cap*, at the summit of which, a few large irregular cells can be seen (the remains of the *suspensor* of the embryo) ; note the loose arrangement of the cells at the free part of the calyptra, becoming more close as you pass inwards.

b. The *initial zone*, consisting of a transversely placed band of cells several layers in thickness, lying at the deeper part of the root-cap. Beneath this zone, can be seen the extremities of—

c. and *d.* The *periblem* and *plerome.* By divisions of the cells of the initial layer, additions are made to the central part of the root-cap on the one hand, and the periblem and plerome on the other.

e. The lateral parts of the transverse initial layer can be traced over the summit of the periblem, on to its exterior where it forms an additional initial layer. From this portion of the meristem, there arise the lateral parts of the *root-cap* and the *dermatogen layer*, as may be seen on tracing the cells into the older parts of the radicle.

In this case, there is no separate calyptrogen layer, but the root-cap takes its origin from the same layer of cells as the dermatogen does, and the same initial zone which gives rise to dermatogen and calyptra, also forms the periblem and plerome. In the Maize, on the other hand, the calyptra takes its origin from a special meristem, lying outside that which produces the dermatogen and other parts of the root apex.

iii. Sections of the apex of primary root of **Pinus** will show that there is a well marked plerome cylinder terminating in a rounded apex, outside which lies an initial layer of meristematic cells, from which there arise periblem cells, of which the root-cap is a luxuriant growth, and there is no dermatogen. (See Pinus.)

xxii. Reproduction of Vegetable Cells.

i. Examine in water some **Spirogyra** filaments, which have been kept for some time in darkness with a limited food supply. Look for a filament showing conjugation.

Observe :—

a. Formation of protuberances from adjacent cells of two filaments.

b. Union of these protuberances together.

c. Perforation of the cell walls between the two protuberances.

d. The row of empty cell walls, joined by the passages formed by the united protuberances, to an adjacent filament.

e. The masses of protoplasm in the cells of the latter filament, containing the new cells formed by the conjugation of the protoplasm of the two cells. These new cells are the **zygospores**.

For further details, see page 59.

This mode of cell reproduction is called **conjugation**.

ii. Cut a number of thin transverse sections of the ovary of **Viola tricolor,** just as the flower is beginning to fade. Treat the sections with potash and mount in glycerin, examining with a high power. The ovules will be cut longitudinally. In a fortunate section,

Observe :—

a. The *embryo-sac* of the ovule.

b. In the embryo-sac, make out :—

1. The *protoplasm.*
2. The *cell-vacuole.*
3. Lying in the protoplasm, certain *small cells*, consisting each of a nucleus with a rounded mass of protoplasm, aggregated around it.

   These are young daughter cells, which have been produced *within the mother cell*, from *some* of the protoplasm of the mother cell, the *rest remaining* as the protoplasm of that cell.

This mode of cell reproduction is called **free-cell formation.**

iii. Take the apex of the young primary root of **Pinus,** which has been hardened in Chromic Acid. Place between two layers of elder pith, so as to cut longitudinal sections. Stain in logwood, clear with clove oil, and mount in Canada balsam. Examine with a high power.

Observe :—

a. The *thin cell walls* of the cells of the meristem.

b. The *protoplasm* of these cells, distinguished into an outer hyaline layer not deeply stained (*ectoplasm*), and an inner layer much more deeply stained (*endoplasm*).

c. The large oval *nucleus* deeply stained, in the centre of the cell.

d. In some cells, by careful examination, some of the stages of cell division may be seen.

1. *Elongation* of the nucleus.
2. *Striation* of the nucleus in a longitudinal direction, and the accumulation of protoplasm around its poles, so as to form the so-called *nuclear-spindle.*
3. Separation of the nuclear-spindle into two parts, by division across its middle.

4. Collection of the protoplasm around these two parts of the spindle.
5. Formation of a new thin cell wall across the middle of the cell, and the rounding off of the two parts of the nuclear-spindle to form the new nuclei of the two daughter cells.

This mode of cell formation is ordinary **fission**, in which *no rounding off* of the daughter cells occurs, and in which a new cell wall is *only* formed along the *plane of division.*

iv. Cut very thin transverse sections of a young flower bud of **Tropæolum majus**. Examine the sections of the anthers in glycerin, with a high power.

Observe :—

The development of the pollen grains in the anther lobes.

1. The formation of four daughter cells *within* each mother cell.
2. As each daughter cell is being marked off, and before they are quite separate, they produce *new cell walls* around themselves, distinct from the mother cell wall.
3. During this process, each daughter cell becomes *rounded off*, and new cell wall is eventually formed from the *whole* of its surface. (See page 142.)

This mode of cell formation is that variety of **fission**, in which danghter cells are formed in the mother cell, a *rounding off* takes place, and cell wall is formed from the *whole* surface of the daughter cells.

Other methods of cell formation by **rejuvenescence** as seen in Oedogonium, and the peculiar form of **fission** seen in Spirogyra, are difficult to demonstrate.

PART II.

THE CRYPTOGAMIA.

1. The Fungi—Torula.

i. Examine the **Torula** with a high power, and make out the details of its structure, following the directions given in General Morphology (page 9).

ii. Determine the influence of **temperature** on the growth of the Torula, by the following experiments :—

A. Take three test tubes *a*, *b* and *c*. In each place an equal quantity of Pasteur's solution, and an equal quantity of yeast. Keep (*a*) in a warm place at temperature 35° C.; (*b*) place in melting ice (0° C.); leave (*c*) at the ordinary temperature of the room. After a time, compare the growth in each tube, judging it by the amount of turbidity :—

(*a*) Very good growth.
(*b*) No growth at all.
(*c*) Moderate growth.

B. Having satisfied yourself that no growth takes place in (*b*), remove it from the ice and keep it at the ordinary temperature of the room.

Observe :—

That growth takes place in it as in (*c*). Cold therefore checks the growth, but does not kill the Torulæ.

C. Take a tube containing some Pasteur's solution and a drop of yeast. Heat it to near boiling point, and plug with cotton wool.

Observe :—

That no growth takes place in it. The Torulæ have been killed.

For all physiological processes in plants, there is a maximum, minimum and optimum temperature. These, for the life of Torula may be determined by trial. They are:

Min. about 0° C.
Opt. „ 35° C.
Max. „ 50° C.

iii. Observe the effect of **light** on the growth of Torula, by sowing similar quantities in two test-tubes of Pasteur's solution. Expose one to light, and keep the other in a dark place.

Observe:—

No difference between the growth in the two tubes, provided the temperature has been the same in each.

iv. Influence of **food supply**. Take four test tubes *a*, *b*, *c*, *d*; in (*a*) place some *water* (distilled); in (*b*) some water with a little cane sugar in solution; in (*c*) some Pasteur's solution without sugar; in (*d*) ordinary Pasteur's solution. Put in each an equal quantity of yeast. Keep all the tubes at 35°C.

Observe:—

In (*a*) growth very little (if any)
(*b*) some growth, but not good,
(*c*) fairly good growth,
(*d*) very good growth.

The growth in (*a*) and (*b*) will only continue so long as the salts which form the food adhering to the yeast, last. In (*c*) and (*d*) all the salts necessary for growth are present.

v. Determine the **effects** of the Torula on the fluid in which it lives.

A. *Carbon dioxide* is evolved. Take two test tubes; in one, put some Pasteur's solution and yeast; in the other, some lime water; connect the two by means of a glass tube with close fitting corks, so that the end in the lime-water tube dips below the fluid, and place in a warm situation. Gas will slowly bubble from tube (*a*) to (*b*).

Observe:—

A *precipitate of Carbonate of Lime*, showing that CO_2 is evolved.

B. *Alcohol is produced.* This can be shown by taking some Pasteur's solution in which yeast has grown for some time, distilling it, and testing the distillate for alcohol.

C. *Heat is formed.* Take two flasks, place in (*a*) some Pasteur's solution and yeast; in (*b*) yeast and water. Fit each with a loose cork supporting a delicate thermometer. Cover over with felt, and leave for some time.

Observe :—

Temperature of (*a*) is higher than that of (*b*).

vi. Determine the **effect of limiting the food supply.** Wash some dry German yeast in water; allow to settle. Spread some of the washed yeast on slices of fresh potato and place in a moist situation under a bell jar. From day to day, examine some of the growing yeast.

Observe :—

The presence of *three* or *four* small cells in each Torula-cell. These are **Endogonidia,** and have been produced by endogenous division of the Torulæ.

vii. Sow some yeast in Pasteur's solution without sugar. After some time, distil as in v. B., and determine that *no alcohol* is present.

ii. Fungi—Schizomycetes (*Bacteria*).

i. Obtain some urine or other animal fluid, and leave it exposed to the atmosphere until it becomes turbid and acquires a strong odour of putrefaction. Note that a scum forms on the surface of the fluid. Take some of such a putrefying liquid, place on a glass slide, cover and examine with a very high power.

Observe :—

a. The **Bacteria,** consisting of short cylindrical or rod-like bodies, sometimes elliptical or rounded at their extremities. Occasionally they form short jointed rows, or very commonly appear as dumb-bells, showing that they are in the act of dividing.

b. Their *size.* Very minute, about $\frac{1}{20000}$th to $\frac{1}{12000}$th of an inch in diameter, and about three times as long. They vary somewhat.

c. They are *mobile*, exhibiting two movements: (1) purely physical, rotatory, around a definite fixed spot (*Brownian* movement); (2) vital, oscillatory or spinning movement, leading to definite locomotion. This latter movement is due to the action of extremely minute flagella at one or both extremities. These flagella can seldom be seen.

d. Their *structure.* Very little can be made out, but generally there may be seen an outer transparent layer, probably *cellulose*, surrounding an inner less transparent substance (protoplasm, or so called *microprotein*).

e. They multiply by *fission.* Some can be seen of a dumb-bell shape, *i.e.* with a constriction in their middle, showing that they are in the act of dividing. Others are seen, forming rows or chains, consisting of those which have rapidly divided and not yet separated.

ii. Make an infusion of hay, by means of water, filter and set aside till the fluid becomes turbid, and has a scum on the surface. Examine in the same way.

Observe :—

The points detailed above.

iii. Examine with a very high power, some of the scum either from a hay-infusion or from a putrefying animal fluid.

Observe :—

A *gelatinous material* forming a sort of matrix, in which are imbedded hosts of minute short, rounded or elongated motionless Bacteria, like those described above.

This is what is called the *zooglœa* or *resting state.*

iv. Examine carefully some hay infusion with a high power. In addition to the Bacteria described above,

Observe :—

Bacilli, consisting of threads of rod-like bodies relatively longer than Bacteria. The threads are straight or zigzag rows of bodies having the same structure as Bacteria. Here and there, may be seen shorter chains of these rod-like bodies, consisting of two or three Bacilli, or even isolated ones. The isolated Bacilli are motile; the threads are not. Threads have been produced by repeated division of single Bacilli. Threads of Bacilli constitute what is known as the *leptothrix* state.

v. If some suitable nourishing medium be taken, such as pork broth, and a drop of a hay infusion placed in it, and the whole kept at a temperature of about 35° C. in an incubator for twenty-four hours, the Bacilli can be obtained in greater numbers, and when examined are found either in the condition described in iv., or in a state of zooglœa.

vi. Examine with a very high power some blood which has been exposed to the atmosphere for some days.

Observe :—

Micrococci. In addition to Bacteria, are seen large numbers of extremely minute spherical organisms or micrococci. They occur either singly or in twos (diplococcus) or in rows. They consist of a cell wall and contents, only to be made out with very high powers. They multiply by fission, and may occur in a zoogl&oelig;a state.

vii. In hay infusion, there may be found other forms of Schizomycetes.

a. **Vibrio,** consisting of two or more joints, but bent so as to have a partial twist. By the action of their flagella, these may be seen rotating on an axis, giving the appearance of a serpentine motion.

b. **Spirillum,** consisting of an unjointed thread rolled into a spiral and provided with flagella. They are motile, and rotate on their axis so as to appear to have a serpentine motion.

viii. Study some points in the **Physiology** of the Schizomycetes as follows :—

A Take two flasks, and in each put a quantity of freshly prepared hay infusion, place flask (*a*) in a warm place exposed to light, and flask (*b*) in a warm place in darkness, leaving the mouths of both open to the atmosphere. After a few days,

Observe :—

That both are *equally* turbid and equally loaded with Bacteria.

B Take three flasks and place in each a quantity of fresh hay infusion. Boil (*a*) and (*b*), but not (*c*) ; whilst (*a*) is boiling, plug the neck of the flask with cotton wool, but not (*b*). Place the three flasks in a warm place, and in a few days examine them.

Observe :—

(*a*) Is quite clear, and presents no sign of Bacterial action. It may be preserved indefinitely *if the plug is not removed.*

(*b*) Is turbid, and contains large numbers of Bacteria.

(*c*) Is more turbid than (*b*), and is loaded with Bacteria.

From this experiment, it is obvious that Bacteria are killed by a boiling temperature, and that after being thus destroyed, new Bacteria can enter from the atmosphere, if the vessel be not properly sealed. By experiments of this kind the doctrine of *Spontaneous Generation* or *Abiogenesis* has been disproved.

(C) Take two flasks. In (*a*) place some fresh hay infusion, and in (*b*) some distilled water. Boil the two fluids briskly for some time, and set aside in a warm place exposed to the atmosphere. After several days examine the two fluids.

Observe :—

(*a*) Is turbid, has a scum upon it, and is loaded with Bacteria.

(*b*) Is quite clear, and has in it very few, if any, Bacteria.

This experiment shows that Bacteria require a certain supply of food-materials, and will only flourish in a proper soil.

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iii. The Fungi—Mucor Mucedo.

i. Obtain some fresh horse dung. Place under a bell-jar, and keep in a warm place for a day or two. When the surface has become covered with numerous white silvery hyphæ, it is ready for examination.

Observe :—

a. The silvery *hyphæ*, forming a crust on the surface of the dung (the *mycelium*).

b. The straight, erect hyphæ, growing upwards from the surface (*aërial hyphæ*). Note that each terminates in a small globular body (the so-called **sporangium** or spore fruit).

ii. Carefully cut off with scissors some of the **aërial hyphæ**; mount in water, and examine with a high power.

Observe :—

a. The *hyphæ*—straight, unbranched rods, large, presenting a very distinct contour. Trace one, and note the entire absence of septa across the hypha, except near the sporangium. Each hypha presents a distinct *sac* or cell wall of cellulose, containing *protoplasm*, in which are seen granules and vacuoles.

b. The *spore-fruits*, one at the termination of each hypha. Each consists of a rounded sac, the outer surface of which is irregular, owing to the presence of spines of oxalate of lime in the cell wall.

Frequently, the sac is seen to have burst near the base, so as to have separated from the hypha, and the contents are then seen protruding.

c. The *contents of the sporangia.* In the young ones, is found some granular, unsegmented protoplasm, whilst the older ones contain a large number of round masses, held together in a sort of gelatinous material, or separate from each other. These are the **endogonidia.**

d. The *columella*, best seen in those which have burst. It consists of a very thin cell wall, projecting into the interior of the sporangium. It is really a septum dividing the sporangium from the hypha, which has bulged into the cavity of the sporangium.

e. The *endogonidia.* These are small cells, of an oval or cylindrical form, and consist of cell wall and protoplasm.

f. The *collar* around the base of the columella in the burst sporangium.

iii. Make out the structure of these parts better, by staining with Iodine solution.

Observe :—

a. The protoplasm stains.

b. The cell-walls do not stain.

By this means, distinguish the cell wall in—

1. The *hyphæ.*
2. The *sporangia.*
3. The *endogonidia.*

iv. Examine some young **Mucor plants,** which have been produced by sowing the endogonidia in Pasteur's solution.

Observe :—

a. The *hyphæ*, radiating from the endogonidia.

b. They branch.

c. The entire absence of septa in the submerged hyphæ. (The Mucor plant, in fact, is a *single, much-branched cell.*)

d. The aërial hyphæ, produced from the centre of the young plant.

v. Sometimes, one may find some Mucor plants which have **zygospores.** If you are fortunate, you may see these, and the stages in their formation.

Observe :—

a. The production of outgrowths from adjacent hyphæ. These grow towards each other.

b. The union of these outgrowths together.

c. The *zygospore*, lying between two hyphæ; it is rounded, has irregular projections from its surface; is closed off from the adjacent hyphæ. It is formed by conjugation of the outgrowths of the hyphæ.

iv. The Fungi—Penicillium glaucum.

i. Sow some "spores" of **Penicillium** in Pasteur's solution in a shallow dish. Keep in a warm place, and after a day or two, examine the young Penicillium plants with a low power.

Observe :—

a. In very young plants, the presence of one or two little prominences on the surface of the "spore."

b. The development of these into hyphæ radiating from the "spore" as a centre.

c. The branching and elongation of these hyphæ.

d. The formation of *septa* in them.

e. Their gradually interlacement into a dense felt-like mass.

f. The formation of *aërial hyphæ.*

g. The production of a green powdery matter on the aërial hyphæ (new "spores").

N.B.—It would take too long a time to watch these stages on one specimen; but different specimens may be found showing all these stages.

ii. Examine with the naked eye, or a pocket lens, the characters of a fully formed plant.

Observe :—

- *a.* The powdery-looking surface, of a green colour, due to the so-called "spores," or *stylogonidia*, which are borne on the *aërial hyphæ.*
- *b.* The dense, tough, felt-like *mycelium*, consisting of large numbers of hyphæ interlaced. It is colourless.
- *c.* The *submerged hyphæ*, consisting of small, white, branched processes, hanging from the under surface of the mycelium into the Pasteur's fluid.

iii. Take a bit of the **mycelium** and tease up in a little Pasteur's fluid. Cover and examine with a high power.

Observe :—

The interlacing *hyphæ*, consisting of threads, having an outer transparent cell wall, and containing granular protoplasm, with vacuoles and globules of fat. Note the *presence of septa* dividing the threads into a number of elongated cells, placed end to end (compare *Mucor*). Note also the form of the branching of the hyphæ. It is *dichotomous*; branching frequently occurs just behind a septum in the hyphæ.

iv. Tease out in the same way, a bit of the green surface of a **Penicillium.** Cover and examine with a high power.

Observe :—

- *a.* The *conidiophores*, consisting of a single primary erect aërial hyphæ, which divides, in a characteristic manner, into branches; the whole forming a kind of "brush." The summits of the ultimate branches become divided by a number of constrictions into chains of small rounded bead-like bodies (the *gonidia*). On account of their mode of production, they are called *stylogonidia.* (Compare *Endogonidia* of Mucor).
- *b.* The *stylogonidia.* Those at the extremities of the branches, become detached as ripe gonidia. Note that each is of spherical form, has a cell wall, protoplasm and vacuole. The structure may be made more obvious by treatment with Potash solution.

v. Examine some of the Pasteur's fluid in which **Mucor** or **Penicillium** has been growing, cover, and use a high power.

Observe :—

Some small round cells, having the appearance and structure of Torulæ.

They are indistinguishable from Torulæ, and may be best seen when the Pasteur's solution, with growing Mucor or Penicillium, has been kept in a constant state of agitation. They result from the breaking up of the hyphæ of these plants, and are called "Mucor-Torulæ" or "Penicillium-Torulæ."

vi. In rare cases, the second method of reproduction may be seen in Penicillium. Little outgrowths from a hyphæ arise, these grow towards each other, intertwine, and then become enclosed in a dense felt work of small hyphæ produced around them (the *sclerotium*). Within the sclerotium, there is produced a body, consisting of lobose and filamentous processes. From the extremities of the lobose parts of it are produced *asci*, in each of which arise eight *ascospores*. Each of these, develops into a new Penicillium plant.

V. The Algæ—Protococcus.

i. Take some of the green incrustation seen on damp gutters or such places. Suspend in water, and examine a drop with a high power.

Observe :—

a. Size and form of **Protococcus** cells.

b. Their structure.

1. *Cell wall.*
2. *Protoplasm*, no nucleus visible.
3. *Green colour*, due to the presence of *chlorophyll*, sometimes red.

ii. Stain with Iodine.

Observe :—

a. Staining of the protoplasm.

b. Cell wall not stained.

c. A blue coloration sometimes (*starch*).

iii. Crush.

Observe :—

Protoplasm (stained) and burst *cell wall*.

iv. Stain with Iodine and Sulphuric Acid.

Observe :—

Blue coloration of the cell wall (*cellulose*).

v. Sometimes, two or four cells are found adhering together. This is owing to the fact that a protococcus has just divided *by fission*. When simple fission occurs, a new cell wall is formed only along the plane of division. Sooner or later, the young protococci separate.

vi. Occasionally, one finds protococci in a **motile state**. Mount some water containing motile protococci and examine with a high power.

Observe :—

a. Pyriform cells, consisting of a colourless cell membrane, surrounding a mass of green protoplasm accumulated towards the narrow end of the cell. The protoplasm is free from the cell wall, except at the narrow end of the cell, and is separated from it by a space. Two cilia are found projecting from this narrow end of the cell and are continuous with the protoplasm at this spot. By the action of these cilia, rapid gliding movement of the cell through the water is produced.

b. Sometimes similar cells are seen, consisting of simply a naked mass of protoplasm, without any cellulose cell wall.

vii. The main difference between the **physiology** of protococcus and that of Torula is the function associated with the presence of chlorophyll, in the former. Owing to the existence of this substance, the protococcus can decompose carbon dioxide gas, in the presence of sunlight, and obtain its carbon from this source.

To demonstrate this, an experiment of the following kind should be done :—

Take three test tubes, *a*, *b*, *c*; half fill them with mercury; in *a* and *b*, place enough water containing large numbers of protococci to fill the tube; fill *c* with distilled water; invert over mercury and introduce about an equal quantity of carbon dioxide into each. Place *a* in sunlight, *b* in darkness, *c* in sunlight. After a few days, examine and determine the chemical nature of the gas at the summits of the three tubes. It will be found, that the tube (*a*) exposed to sunlight contains chiefly oxygen gas, that in the others is carbon dioxide. Oxygen, therefore, is exhaled and carbon dioxide decomposed by those plants which contain chlorophyll, *under the influence of sunlight.* The experiment may be repeated for Torula, and it will be found, that it has no power, under any circumstances, of decomposing carbon dioxide gas.

vi. The Algæ—Spirogyra.

i. Mount in water, a portion of a filament of **Spirogyra** Examine with a low, and afterwards with a high power.

Observe :—

a. The single row of elongated cylindrical cells, placed end to end.

b. Between adjacent cells a transverse partition (cell wall), common to the two adjacent cells.

c. In each cell note :—

1. The *cell wall*, continuous from cell to cell, and with the common transverse partitions.
2. The *protoplasm.* The greater part of this forms a layer lying immediately beneath the cell wall (primordial utricle). From this, there pass a number of delicate threads of protoplasm, converging towards the centre of the cell, where they unite into a little mass of protoplasm surrounding :—
3. The rounded *nucleus.*
4. The spirally-twisted band of *chlorophyll* lying in the primordial utricle. It is seen to make two or three complete turns round the cell. Its margins are irregular. Lying in it, are usually seen several groups of starch grains arranged in a characteristic wreath-like manner. A few bright refractive oil globules are also seen.
5. The large *vacuole,* lying within the layer of primordial utricle. In it, the nucleus is found surrounded by a small mass of protoplasm. The vacuole contains the *cell-sap.*

ii. Treat a filament of **Spirogyra** with alcohol, then stain in Spiller's purple or eosin, and mount in dilute glycerin.

Observe :—

a. The *protoplasm*, stained and more distinct.

b. The *nucleus*, deeply stained and now quite distinct, in the middle of the cell.

iii. Stain a filament with Iodine.

Observe :—

a. The protoplasm, nucleus, and chlorophyll band stained brown.

b. Blue coloration of the rounded starch grains in the chlorophyll band.

iv. Mount in water some **Spirogyra** filaments, which have been kept in darkness and with a limited supply of food for some time, and look for pieces showing **conjugation**.

Observe :—

a The formation of protuberances from the adjacent sides of the cells of two adjacent filaments.

b. The growth of these protuberances towards each other until they meet.

c. The portions of cell wall separating the protuberances break down, so that the cavities of the two cells become continuous.

d. Shrinking of the protoplasm in the conjugating cells, so as to form rounded masses separated from the cell walls by a space.

e. The passage of the protoplasm from one of the conjugating cells, across the open passage, into the other cell, where coalescence takes place between the two masses of protoplasm.

f. An empty filament, consisting simply of the cell walls and the remains of the outgrowths, may be seen. Attached to such a filament, may be seen another, in which the cell walls remain, each one enclosing a rounded brown-coloured body, the *zygospore.*

g. *The zygospores.* Each consists of a *thick cell wall*, containing brown granular-looking protoplasm.

v. Mount in glycerin, some filaments of **Spirogyra**, which have been treated as follows :—

Whilst in an active state of cell division (which only occurs at night), the filaments are placed in weak spirit, which kills them and preserves them in the various stages of fission.

Observe :—

a. Contraction of the protoplasm from the cell wall.

b. Commencing constriction into two parts by an equatorial groove around it.

c. Growth into this groove of an annular projection from the inner surface of the cell wall.

d. Greater and greater constriction of the protoplasm, and deeper and deeper growth of the annulus of cell wall.

e. Complete division, the annulus of cell wall now forming a complete disk, separating the daughter-masses of protoplasm.

N.B.—Some or all of these stages may be found, but they are sometimes difficult to obtain. The behaviour of the nucleus may be seen by staining the filaments with Spiller's purple, or with hæmatoxylin. Division of the nucleus is only complete when division of the cell is nearly accomplished.

vii. The Algæ—Fucus vesiculosus.

i. Examine carefully with the naked eye, the external features of a **Fucus** plant.

Observe :—

a. *Greenish-brown* colour.

b. Tough cartilaginous consistency.

c. The *absence* of any distinction into *root*, *stem*, and *leaf;* such a vegetative structure is a *thallome.*

d. The thallome is attached to stones or other objects by means of a *disk*, which is large and branched.

e. The *form* of the thallome ; in the lower parts, narrow and cylindrical ; higher up, flattened and strap-like.

f. The *branching* of the thallome. The branches are all in one plane, and are arranged on the *dichotomous* plan.

g. Rounded terminations of the younger branches, where growth of the thallome is proceeding.

h. A thickening in the middle of the thallome ; it runs down it longitudinally, and branches in the same way as the thallome. The dichotomy can be well seen by tracing this thickening up into the younger branches.

i. Here and there, are rounded swellings, having a resistant elastic feel. These are *air-vesicles.*

j. Covering most of the surface of the thallome are small dots, corresponding to depressions of the surface, projecting from which, are small tufts of hairs.

k. The extremities of some of the branches present a different appearance to the rest. They are rougher, swollen, and have very distinct dots upon them. These dots have bunches of hairs projecting from them. They correspond to the mouths of large cavities in the thallome, in which the reproductive organs are developed, and are known as *conceptacles*. The branches having this appearance are the *fertile* ones.

l. General slimy feel of the whole plant, due to the presence of a large quantity of mucilage in its tissues.

ii. Cut across one of the **fertile branches.**

Observe :—

a. The greenish-coloured tissue at the surface (so-called *epidermis*).

b. The colourless, gelatinous looking, soft tissue in the centre.

c. The rounded green-coloured *conceptacles*, depressed beneath the surface of the thallome.

iii. Place a piece of the **thallome** in alcohol for a short time (so as to remove some of the water, and render it easier to cut). Then cut thin transverse sections of it. Mount in glycerin. Examine with low and high powers.

Observe :—

a. The closely-crowded, dark coloured cells at the surface. They are small, and arranged in a prismatic layer, distinct from the tissue beneath. This layer may be called *epidermis*. Note the cell walls and brown granular contents—protoplasm, containing a colouring substance allied to chlorophyll.

b. The lighter tissue inside, consisting of round cells.

Note :—

1. The *common cell wall*, colourless, swelling greatly in water, appearing like a sort of "intercellular substance." It is composed of mucilage.
2 The second layer of *cell wall*, special to each cell. It is colourless, thick, and transparent, and firmer and more compact than the common cell wall.
3. The granular *cell contents*, of a brownish-green colour, and consisting of protoplasm and a special colouring substance.

iv. Cut thin transverse sections of a **fertile branch**, having previously kept it in alcohol for a short time. Examine with a low and high power.

Observe :—

a. The *general substance* of the thallome, consisting in this situation, of branched rows of cells, smaller than in the lower parts of the thallome, each cell, however, having the same general structure as above.

b. The *epidermal* layer. Trace this till you come to the mouth of a conceptacle. Here it is seen to become continuous, with the layer of cells lining the conceptacle. (The conceptacle is, in fact, developed by a depression of the surface of the thallome.) The structures, therefore, which arise from the walls of the conceptacles, are morphologically trichomes.

c. The structures within the conceptacles. These are :—

1. *Sterile hairs*, consisting of long unbranched rows of cells. They are very numerous, and a large number of them project from the mouths of the conceptacles.
2. Somewhat shorter hairs, which, however, are branched. They consist of many cells, and where they branch, are seen two or three oval cells of darker appearance than the rest. These cells have very granular contents. They are the *Antheridia*, or male organs of reproduction. In them, subsequently are produced the *antherozooids*.
3. A third kind of trichome, consisting of a short cubical basal cell, and a single, much larger globular one, having a thin cell wall and very dark granular contents. These are the *Oogonia*, or female organs. Very often the contents of the globular part of the oogonia can be seen to be divided more or less completely into *eight* segments. Sometimes, these eight segments are seen as very distinct rounded bodies within the oogonia. They are the *Oospheres*. By the union together of the antherozooids and the oospheres, fertilization is effected, an *Oospore* being the result of the fertilization. Note that each oosphere has a nucleus, but no cell wall of its own.

viii. The Characeæ—Chara—Nitella.

i. Examine with the naked eye a **Chara** plant.

Observe :—

a. The central slender, green, elongated *primary axis* or *stem.*

b. The appendages given off from this axis in a series of whorls. These are the *leaves;* there are several of them in each whorl (*eight* or *ten*).

c. The parts of the stem from which the leaves are given off, and the lengths of stem between the successive whorls. These are the *nodes* and *internodes.* As you pass upwards toward the summit, the stem becomes smaller, and the whorls of leaves closer together, so that the internodes are *shorter* near to the summit.

d. The *terminal bud,* consisting of several whorls of leaves crowded together and covering over the apex of the stem.

e. The *leaflets.* Short lateral appendages borne, at intervals, on the leaves.

f. The *reproductive organs.* These are situated on the lower parts of the leaves, in the same positions on the fertile leaves, as is occupied by the leaflets. A few leaflets frequently surround them. There are two kinds of reproductive organs, which are attached to the leaf close together, female or *nucules,* and male or *globules,* the latter globular and the former flask-shaped. They have a dark-brown or orange colour, when ripe.

g. The *branches* of the primary axis. Sometimes no secondary axes or branches are seen; at other times branches are found, and when so, only *one* branch is given off from each node. They are never given off elsewhere than in the axils of the leaves. When several successive nodes bear a branch each, in the axil of one of the leaves, the branches are not placed opposite each other, but are arranged along a spiral line winding round the stem. The branches have the same general appearance as the primary stem, bearing leaves and having terminal buds.

h. The *rhizoids.* Moderately long hyaline filaments, which grow downwards from the lower nodes of the primary stem, and serve to fix the plant as well as obtain some of the food. They are, morphologically, quite distinct from true roots.

ii. Examine with a low power, an internode of the **stem** of **Chara.**

Observe :—

a. A zig-zag line across the middle of the internode, corresponding to the line of junction of the two series of cortical cells of the internode.

b. Above and below the zig-zag line, the spirally-arranged long *cortical cells* of the internode.

iii. Hold a piece of the internode of a **Chara stem** between two layers of elder pith or of carrot, and cut thin transverse sections. Examine with a high power, in glycerin.

Observe :—

a. The large central *internodal cell*, having a *cell wall*, a thin layer of protoplasm forming a *primordial utricle* and a large central *cell-cavity.*

b. The *cortical cells*, forming a single complete layer, covering the central internodal cell. Make out their structure, staining with logwood solution.

iv. In the same way, cut and examine longitudinal sections of a **stem**, taking care that they pass through a node and parts of the two adjacent internodes.

Observe :—

a. The single central long *internodal cell*, surrounded by—

b. The long tubular *cortical cells.*

c. The *nodal cells.* Two or three, or more in number, small and narrow, appearing as a mere septum interrupting the continuity of the cavities of the internodal cells.

d. The attachment of the bases of the leaves to the nodes, and the continuity of the tissue of the leaves with that of the nodes.

e. The continuity of the cells of the node, and those of the leaves, with the cortical cells of the internodes.

f. In the axil of a leaf, may perhaps be seen a section of a *bud* of a branch.

v Stain some transverse and longitudinal sections in hæmatoxylin or carmine, previously dissolving out the chlorophyll by means of alcohol. Examine with a high power.

Observe :—

In each cell,

a. *A cell wall.*

b. *Primordial utricle* of protoplasm, in which lie numerous chlorophyll bodies (stained).

c. *Vacuole.*

d. *Nucleus* (only seen if your section has been fortunate).

vi. Examine the **terminal bud** of a Chara stem according to the directions given at page 40, *or* specimens which have been treated with Chromic or Picric Acid and preserved in spirit, may be used. They may be stained in logwood or carmine, then cleared and dissected in clove oil, and finally mounted in Canada balsam.

vii. Examine with a low power, a **leaf** of **Chara.**

Observe :—

a. The succession of *nodes* and *internodes*, the latter covered by cortical cells, as in the stem; the former bearing leaflets and (in some cases) reproductive organs.

b. The *apical cell* of the leaf, consisting of a large conical pointed cell. The leaf, when first formed, grows by means of subdivisions of this apical cell; but the growth soon ceases, so that the leaf does not increase after it has attained a certain size.

viii. Examine with a high power the **terminal cell** of a **leaf** (which, on account of the absence of any cortical cells, can be easily studied with a high power).

Observe :—

a. Regularly arranged *chlorophyll corpuscles*, large oval bodies, lying in oblique rows. These are contained in the peripheral layer of the primordial utricle of the cell.

b. The *white line*, passing obliquely up the cell, and formed by a band in which no chlorophyll bodies lie.

c. *Rotation* of the deeper layer of protoplasm, passing as a current up one side of the white line and down the other. No movement in the white line itself.

ix. In sections of a leaf, it can be shown that they have the same essential structure as the stem.

x. Mount in water one of the **rhizoids** of Chara. Examine with a high power.

Observe :—

A single row of cells, slender, thin-walled, exhibiting rotation of protoplasm. They present a swollen appearance where two cells join.

xi. Cut off a **fertile leaf** of **Chara,** and examine in glycerin with a low power.

Observe :—

a. The *globule*, orange-coloured if ripe, greenish if young. On its surface, make out the outline of the eight cells or segments, which make up its outer wall (*shields*). The margin of each shield is deeply dentated. They are arranged in two sets of four. The four upper shields are triangular in form, the four lower somewhat quadrilateral. Each globule has a short stalk, and appears dark in its globular part, except around the margin, where there is a clear band, owing to the dark contents of the shields not lying in the peripheral parts of the cells.

b. *The nucule.* It has an oval or somewhat flask-like form. Around its lower part are seen five spirally-twisted cells (*encircling cells*), each terminating at the summit of the nucule in a single short, somewhat pointed cell. There are thus, five of these short cells surrounding the neck of the nucule ; they form the *corona.* In the young state, the neck is closed by these crown-cells ; but they separate when the nucule becomes ripe.

xii. Take a ripe **Globule,** and tease it in water. Put on a cover-glass and gently press out its contents. Examine first with a low, and then with a high power.

Observe :—

a. The flattened external *shields*, of a brown colour, each a segment of a sphere.

b. The somewhat elongated cylindrical cell, attached perpendicularly to the centre of the inner surface of each shield—the *manubrium.* It has clear contents, and exhibits, if not too old, the rotation of protoplasm.

c. Attached to the inner extremity of the manubrium, is a short cubical cell, known as the *primary capitulum.*

d. Around each primary capitulum and attached to it, are seen *six secondary capitula*, smaller cubical cells, with clear or slightly granular contents.

e. *Four* narrow elongated slender *filaments*, attached to each secondary capitulum.

f. Each filament consists of a large number of small compressed, cubical or disk-like cells, united into a single row. These cells, when ripe, are each seen to contain a single, spirally coiled *Antherozooid.* When not quite ripe, each is a mother cell of an Antherozooid, and then contains a nucleated mass of protoplasm.

g. The *Antherozooids* are sometimes found free; they are then seen, with a high power, to consist of a rather swollen extremity or *head*, tapering into a *body* which makes one or two turns of a spiral, and terminates in *two* long hyaline *cilia.*

xiii. Take a young **nucule**, which has been treated with Chromic or Picric Acid, clear it with Potash, and press out under a cover glass in glycerin.

Observe :—

a. The large central cell, in the swollen globular part of the nucule. This is the *oosphere.*

b. The five *encircling tubes*, terminated by :—

c. The five *crown-cells.*

d. The single *stalk-cell* at the base.

xiv. If Chara cannot be obtained, work with **Nitella**, which agrees in the main with Chara.

Observe :—

a. The absence of any covering of cortical cells in the internodes of the stem and leaves, so that this type serves better than Chara to observe the rotation of the protoplasm, which may be seen in any of the cells of the stem or leaf.

b. At the terminations of the fertile leaves are seen :—

1. Two lateral *leaflets.*
2. A *single* terminal globule, having the same structure as the globule of the Chara. It occupies the extreme apex, and is formed by a metamorphosis of the apical cell of the leaf.

3. When the single globule is nearly ripe, there are seen *two* young nucules just beneath it, developed in, as it were, the axils of the two lateral leaflets of the summit of the leaf.

c. The spirally-twisted encircling cells of the nucules are each capped by *two* crown-cells, not one.

d. When branches are formed at the nodes of the stem, *two*, instead of one, are produced from each whorl, in the axils of *two* opposite leaves.

e. In other particulars Nitella resembles Chara.

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ix. The Muscineæ — The Oophore generation.

i. Examine the naked eye characters of a young plant of **Funaria hygrometrica.**

Observe :—

a. The *stem* or axis, consisting of a toughish stalk of cylindrical form and brown colour. On it, are seen :—

b. Closely-crowded *leaves*, delicate, flat, green, sessile upon the stem, ovoid in form, with pointed extremities. On careful examination, these are seen to be arranged in *three* rows passing around the stem in the form of parallel spirals.

c. At the base of the stem, where it is attached to the soil, are numbers of small brown filaments, which serve to attach the plant to the soil. These are the *rhizoids* or *root-hairs*. They are not true roots.

d. *Reproductive organs*, borne on the summit of the stem, (*acrocarpous* Mosses), and surrounded by numerous leaves crowded near the summit. In the male plants, they are of *brownish* colour, and in female plants, of a *purplish* tint and almost covered by surrounding leaves.

ii. Cut thin transverse sections of the lower part of the stem of **Funaria hygrometrica,** holding it between two layers of elder pith or of carrot. Mount in glycerin and examine with a high power.

Observe :—

a. The *outermost layer of cells*, of dark brown colour, small, but with thick cell walls.

b. Internal to this, two or three layers of cells, whose walls are still of a dark brown colour and thickened. As you work from the exterior inwards, you find that the cell walls are less and less thickened and the cells become larger.

c. Internal to these layers of sclerenchymatous tissue, are several layers of larger, thin-walled, colourless *parenchymatous* cells.

d. Occupying the axis of the stem, is seen a central mass of very thin-walled small cells. This central mass of cells is sometimes regarded as a rudimentary *fibro-vascular bundle*, but beyond these small cells, which in longitudinal sections are seen to be elongated and somewhat cambiform in shape, there are not found in the axial cells of the Moss anything, comparable to the proper cells of fibro-vascular bundles in higher types.

iii. Mount in glycerin one of the leaves of **Funaria.** Examine with a low power.

Observe :—

a. A central *midrib*, running up the leaf and dividing it into two lateral halves.

b. In each half, a single layer of cells forming the flattened expanded part of the leaf. Each cell contains numerous rounded chlorophyll corpuscles imbedded in colourless protoplasm.

c. In the region of the midrib, there are several layers of cells, which are narrow, thin walled, and elongated, like those found in the axial tissue of the stem, and supposed to be a continuation of the rudimentary bundle of the stem.

iv. Mount in glycerin some of the rhizoids from **Funaria.** Examine with a high power.

Observe :—

Each rhizoid consists of a single irregular row of cells, whose cell walls are somewhat thickened and are of a dark brown colour. The cell contents are granular protoplasm, containing oil globules. The cells are separated by thin oblique septa.

v. Cut off with scissors, the summit of a fertile **male plant** of **Funaria**. Place in glycerin on a slide and dissect it with needles.

Observe :—

a. That a group of reproductive organs terminates the *primary axis* of the plant (acrocarpous Mosses).

b. The more or less expanded broad delicate leaves of a pale green colour, which form a sort of "perianth" around the reproductive organs within. These "perianth" leaves are the *perigonium*.

c. The closely packed, brownish or orange coloured *Antheridia*, occupying the centre of the ring of "perianth" leaves.

vi. Having teased up the **reproductive organs**, mount in glycerin and examine first with a low, then with a high power; or cut longitudinal sections, by placing between two layers of elder pith, and mount in the same way.

Observe :—

a. *The Antheridia.* Long, club-shaped bodies, forming a large group at the somewhat expanded summit of the stem. Each Antheridium has a *stalk* made up of two or three rows of cells, and an elongated cylindrical *body*, consisting of a single layer of flattened cells forming a wall, and a large central mass of numbers of round or spherical cells.

In an Antheridium which has been broken, the large central mass may be seen to be held together by a gelatinous material. These small cells are the *mother cells* of the Antherozoids, and each produces a single Antherozooid.

b. *Paraphyses*, consisting of long hair-like bodies occurring amongst the Antheridia. Each consists of a single row of cells; some are terminated by a globular cell. These are not reproductive in nature, being only sterile hairs.

vii. At the summit of a **female plant** of **Funaria**, make out :—

a. A *terminal bud*, consisting of numbers of leaves folded over the summit, and covering over the reproductive organs.

The leaves are similar to the ordinary foliage leaves, and there are several layers of them becoming smaller towards the centre of the bud. They form the *perichætium*.

b. The dark central, purplish or brownish spot, in the centre of the bud and nearly hidden by the encircling leaves.

This body is the mass of *Archegonia*.

viii. Cut off the summit of a female **Funaria** and tease it up carefully in glycerin; examine with a low and afterwards with a high power.

Observe :—

a. The *Archegonia*, they are of a purplish or brownish colour, and each consists of :—

1. A short *stalk*, broad and stout, of several rows cells.
2. A *body* or ventral part, consisting of an ovoid swelling, whose wall is made up of *two* layers of cells, and which contains a large central dark cell or *oosphere*.
3. A *neck*, a long tube surmounting the ventral portion. In the *young state*, it consists of a wall made up of a single layer of cells arranged in four longitudinal rows, and a tube closed at the summit, and containing a central or axial row of "*neck cells*." In the more *mature state*, the cells of the wall separate at the summit, so as to leave an opening leading into the tube of the neck, which is not now filled by an axial row of "neck cells."

b. The *paraphyses*, hair-like bodies lying amongst the Archegonia.

N.B.—It is difficult to make out the characters of the punctum vegetationis of the Moss, but when it is seen, it is found to consist of a single apical cell with three faces and a rounded base, *i.e.* it has somewhat the form of a triangular pyramid, its apex is directed towards the tissue of the stem, and segments are cut off from it in regular succession by segment planes nearly parallel to its three faces, in order. Each segment of the mother cell produces *a leaf*, as well as contributing to the general meristem at the summit. There are thus *three* rows of leaves.

x. Muscineæ—Sporophore generation.

The Sporophore generation, or Sporogonium of a Moss, is formed from the fertilized oosphere of the oophore generation, and develops within the archegonium, which it usually, sooner or later, ruptures in its growth ; but the sporophore is *never separate* from the oophore, on which it is seen as a terminal fructification. The most conspicuous stage in the life history of a Moss is thus, the *oophore generation* (Cf. Felicineæ).

i. Examine with the naked eye, or with a pocket lens, a **Funaria** plant, in which the sporogonium is nearly ripe

Observe ;—

a. The *stem, leaves, and rhizoids* of the oophore.

b. The *sporogonium*, consisting of :—

1. The *seta*, a narrow, or slightly curved, cylindrical stalk, attached below to the summit of the oophore, where it is surrounded by a number of large leaves.
2. The *capsule* or *theca*, borne on the summit of the seta, and consisting of an obliquely pear-shaped body (of a greenish colour when immature and brown when ripe).
3. At its summit, is seen a small cap-like body provided with a short filament. This is the *calyptra.* It is not, properly speaking, a part of the sporogonium, but is really the remains of the archegonium of the oophore.

ii. Examine a plant of **Polytrichum**, in which the sporogonium is nearly ripe.

Observe :—

a. The parts of the oophore.

b. The *sporogonium*, consisting of a long *seta*, stiff, cylindrical, stouter than that of Funaria, firmly attached below to the apex of the oophore, and terminating above in the *capsule.* This is covered by an extremely conspicuous *calyptra*, which completely hides the capsule, and which has a large number of long, stiff hairs projecting downwards from its edge. On separating the calyptra, the oblong, smooth capsule is seen. It is, at its extremity, of a conical pointed form.

iii. Pick out a nearly ripe **capsule** of Funaria, hold it between two layers of elder pith in such a way as to cut longitudinal sections. Mount in glycerin, after treatment with potash, and examine with a low power.

Observe :—

a. The *base* of the capsule, consisting of small-celled tissue, with thin cell walls, continuous with that of the seta.

b. The *wall* of the capsule, made up of three or four layers of cells, continuous below with the cells of the base.

c. A *central* mass of tissue, consisting chiefly of large parenchymatous cells, continuous at the summit of the capsule with the cells of the wall, and attached below by a sort of stalk of cells to the tissue at the base. This central mass of cells forms the *columella.*

d. A *space* lying between *b* and *c*, traversed by a few narrow filaments of cells. These, as well as the stalk of the columella, are very often broken away in making the sections.

e. The tissue at the summit of the capsule, continuous with the wall laterally, and with the columella below.

iv. Examine your thinnest and most median section with a high power, previously clearing it with potash, if not sufficiently transparent.

Observe :—

a. The wall of the capsule, made up of :—

1. An external *single layer* of flattened cells, whose walls are cuticularised and of a brown colour. The outer cell wall forms a distinct *cuticle.* Sometimes stomata may be seen in this outer layer of cells, which is a true *epidermis.*
2. Two or three layers of thin-walled parenchymatous cells, containing a few chlorophyll corpuscles.
3. A single layer of smaller cells, darker, and having more granular contents, and containing chlorophyll bodies. These immediately adjoin the air space.

b. The *columella*, made up of :—

1. A central mass of thin-walled parenchymatous tissue. The cells are large, and contain small chlorophyll bodies.

2. A layer of cells in the peripheral parts of the columella, distinct from the rest by their dark brown colour. The cells of this layer are quadrilateral in form, possess dark granular contents, and are considerably smaller than the central cells of the columella. These are the *mother cells* of the spores.

3. The *spore sac*, consisting of a single layer of small thin-walled cells immediately inside the layer of mother cells, and of two or three layers of similar cells lying outside the layer of mother cells. This outer layer forms the external boundary of the columella, and passing from it, are seen rows of similar cells traversing the air space and connecting the columella with the wall of the capsule.

c. *The tissue at the summit of the capsule*. Here the wall and the columella are continuous. The epidermis in this region, together with the more superficial of the subjacent cells, become differentiated into the *operculum*, which, when the theca is ripe, separates as a lid. The air space cannot be traced into the tissue at the summit, nor can the layer of mother cells of the spores, but the general large celled tissue of the columella can be traced to the summit, where it is covered by the cap-like mass of cells of the operculum. Between this summit of the columella and the cells of the operculum, can be distinguished a layer of cells of brown colour and with thick cell walls. This layer of cells subsequently forms the **peristome**, a structure consisting of a number of appendages, that surround the opening at the summit of the ripe theca, after the separation of the operculum. Around the inferior margins of the operculum, the epidermal cells have a peculiar shape, their outer wall is very thick, and they form a raised ring or *annulus*.

v. Cut thin transverse sections of the **Theca** at various stages Treat with potash and mount in glycerin, examining them with a high power.

Observe :—

The stages in the development of the spores.

1. *Mother cells*, with granular contents and large oval nuclei.
2. *Division* of these into two, and then into four *daughter cells*, each of which develops a cell wall of its own.
3. After separating from each other, each daughter cell divides again into *four* rounded masses of protoplasm, lying inside the cell wall. Each of these four rounded masses develops a cell wall of its own, and becomes a *spore*.

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xi. The Felicineæ — Pteris Aquilina (*Sporophore*).

i. Examine the **external characters** of a plant of **Pteris aquilina**, gathered about the middle of summer. The whole plant must be dug out from the ground, care being taken not to injure the growing part of the rhizome.

Observe :—

a. The *rhizome* or underground stem, a more or less horizontally placed axis, which bears the other parts of the plant. It is of a dark brown colour, except along two lines opposite to each other, where it is lighter (*white lines*). The surface is hard and smooth, except near the apex, where there are numerous dark brown hairs. It has a cylindrical form.

b. The slender, hard, dark brown *roots*, springing from the rhizome irregularly, but chiefly from its lower surface.

c. The *leaves*, or *fronds*, which spring from the rhizome in the position of one of the lateral lines. Not far from the apex, will be seen the position of origin of the fronds of the present year. Some distance further back, the dried remains of the fronds of last year; perhaps also those of the year before last.

Closer to the apex than the leaves of the present year, is seen a small *bud*, consisting of the very young fronds of the next year. This is usually covered by brown, somewhat scaly hairs.

d. *Each frond* consists of :—

1. A long *stalk* or *petiole*, nearly cylindrical, of a brown colour below, green above. It has a few scale hairs upon it.
2. The *lamina* of the leaf, consisting of a central *rachis*, a continuation of the petiole, and a large number of divisions or *pinnæ*, borne upon the central rachis. Each pinna consists of a secondary rachis, bearing a large number of regularly arranged, ultimate subdivisions or *pinnules*.
3. Note the incurved margins of some of the pinnules, constituting the *sori*.
4. In a young frond, note the rolled up extremity of the leaf—*circinate vernation*—(characteristic of Ferns).

e. The *nodes* and *internodes* of the stem, each having the same structure. (Cf. Chara.)

f. *Dichotomous* branching of the rhizome.

g. *Growing point* of the rhizome. It does not have the form of a "terminal bud," but is quite destitute of any covering of leaves. It consists merely of the rounded termination of the rhizome, covered by numerous dark hairs.

ii. Cut across the **rhizome** of **Pteris,** and examine it with the naked eye.

Observe :—

a. The brownish coloured layer of tissue at the surface of the section, consisting of the epidermis and the hardened hypodermal tissue. This brown surface layer is thinner, or even interrupted in the position of the white lines.

b. The general whitish tissue, which forms the greater part of the section, and in which the other tissues are imbedded. This is the *general parenchyma.*

c. Lying in the general parenchyma, an incomplete ring of hard, dark-brown tissue. One or two isolated masses of the same kind may be seen in addition to the ring, either inside or outside it. The ring is usually interrupted in situations opposite to the white lines on the surface. This dark tissue is the *sclerenchyma*, and it, together with the ground parenchyma, forms the *fundamental tissue.*

d. The *fibro-vascular bundles*, consisting of masses of yellowish tissue, not so hard as the sclerenchyma, lying scattered in the ground substance, both inside and outside the sclerenchyma ring. The bundles are not arranged in any definite or characteristic manner, though usually, there can be distinguished a ring of bundles outside the sclerenchyma, and another, less complete, inside it. They vary considerably in size, being usually larger towards the centre of the section.

iii. Cut down the middle of a piece of the rhizome, taking care that your section passes through all the tissues mentioned in ii., and make out the same layers of tissue.

iv. Boil for a few minutes in Schultz' macerating fluid, a piece of the **rhizome** of **Pteris**. Wash in water, and then carefully dissect out the various kinds of tissue mentioned in ii. Having isolated the various bands of tissue, take a bit of each on separate slides, and tease up in glycerin. Examine with a low and also a high power.

Observe :—

a. Cells of the *general parenchyma.* They are thin walled, have intercellular spaces, and are of a more or less polygonal form, being only slightly greater in one direction than the other. On their walls, are seen a few small, almost linear, pits. They contain protoplasm (usually found shrunk into a little mass within the cell).

b. Cells of the *sclerenchyma* ring. They are much longer than broad, have pointed extremities, so as to overlap each other. Their walls are much thickened, and exhibit very distinct stratification and pits.

c. Cells of the *epidermis.* These are flattened, polygonal, elongated somewhat, but not pointed at their extremities. Their walls are much thickened, and two distinct layers can be seen, in addition to the common cell wall dissolved by the macerating fluid, often exhibiting stratification and striation.

d. Cells of the *hypodermis.* Not so flattened as those of the epidermis. They are more or less elongated, somewhat prosenchymatous in form, and exhibit two layers of cell wall, stratification and pits.

e. Cells from the *fibro-vascular bundles.* Those chiefly seen, are the scalariform and spiral vessels. In the scalariform vessels, the extent of the cells composing the vessels can be made out, by observing the oblique interruptions in the rows of ladder-like thickenings. These interruptions correspond to the oblique septa of the original cells.

The spiral thickening can be well traced in the spiral vessels.

v. Cut thin transverse sections of the **rhizome.** Your sections need only include a small part of the thickness of the rhizome, and several sections should be mounted. Some will show one point, others another.

Observe :—

a. *Epidermal cells.*

b. Brown, thick-walled *hypodermis.*

c. Thin-walled *ground-tissue.* Cells contain protoplasm and numerous starch grains.

d. *Sclerenchyma.* Polygonal cells with sharp angles, thick cell walls, pits, common cell wall, and thickened part. (*See* page 20.)

e. *Fibro-vascular bundles.* Examine these according to the directions given at page 27, ii., iii., iv.

vi. Cut thin longitudinal sections of the **rhizome.** Mount in glycerin. Study with a high power.

Observe :—

The same structures as seen under v. Follow the description of the fibro-vascular bundles given at page 28, v.

vii. Study the **sieve tubes** and their **sieve plates**, with a high power, staining the sections, some in Schultz' solution, others in fuchsine or methylene blue.

viii. Cut thin longitudinal sections of the **punctum vegetationis.** Mount in glycerin, and study according to the description given at page 40, ii.

ix. Cut a series of transverse sections from the **apical region,** and mount some from the younger, and others from the older parts.

Observe :—

a. In sections from the older parts, all the characteristic tissues are seen.

b. These become less and less distinct in sections taken progressively nearer the growing point.

c. In sections from the youngest parts, the whole section is made up of similar thin-walled cells (*meristem*).

N.B.—The apical cell is a *triangular pyramid*, with its apex downwards, and divides in such a way that segments are cut off from it, in regular order, by partition walls parallel to its three faces in turn. The characters of the apical cell may be made out better, by means of sections (longitudinal and transverse) of the growing point of the *Male Fern*.

x. Cut thin transverse and longitudinal sections of the **petiole** of a **leaf.**

Observe :—

Essentially the same structure as in the rhizome.

xi. Cut thin transverse sections of the **leaf** of **Scolopendrium vulgare** (Hart's Tongue), which, for the examination of the structure of the leaf, is preferable to Pteris. Take care that your sections pass through the midrib, as well as the adjacent thin part of the leaf. It is better, if they have been previously hardened in alcohol.

Observe :—

a. In the *thin part of the leaf* :—

1. Upper layer of *epidermis*, flattened cells, covered externally by a *cuticle*. The cells contain chlorophyll. There are *no stomata*.
2. Lower layer of *epidermis*, having the same general appearance as the upper; but *stomata* with guard cells are present.
3. The general fundamental tissue between the two layers of epidermis, and known as the *mesophyll*. It consists of thin-walled cells, irregularly and loosely arranged, so as to have large intercellular spaces. The cells are rounded or polygonal, and contain chlorophyll corpuscles.
4. *Fibro-vascular bundles*, cut across obliquely here and there. They lie in the mesophyll.

b. In the *midrib.*

1. Two layers of epidermis.
2. General fundamental tissue, closer, and not so spongy as the mesophyll in the thin part of the leaf. Intercellular spaces smaller.
3. *Fibro-vascular bundle*, single in the middle of the midrib. It is of a roughly triangular form with rounded angles, and apex directed towards the under surface of the leaf. There are bundle and bast sheaths. The xylem takes the form of two crescentic masses, in the centre of the bundle, united together by their convexities, the greater mass of xylem being towards the upper part of the bundle. The phloëm forms a lighter and thinner walled mass of cells, surrounding the xylem, and lying between it and the bundle sheath.

   NOTE.—This tendency to the *collateral* type of bundle.

4. Two small isolated masses of brown *sclerenchyma* lie, laterally, immediately outside the bundle.

xii. Strip off pieces of the **epidermis** from the upper and lower surfaces of the leaf of **Scolopendrium.** Mount in glycerin. Examine with a high power.

Observe :—

a. Sinuous outlines of the *epidermal* cells.

b. Chlorophyll corpuscles *in these cells.*

c. Stomata and guard cells, the latter containing chlorophyll, in the epidermis from the *lower* surface, not in that from the upper surface.

xiii. Cut thin transverse sections of a root of **Pteris**, imbedding it, if necessary. Treat with potash, and mount in glycerin.

Observe :—

a. General brown *fundamental tissue*, not much thickened, except internally, where it forms a thick dark brown layer of *sclerenchyma*, surrounding the central fibro-vascular cylinder.

b. *Bundle sheath*, inside this mass of sclerenchyma.

c. The *Diarch radial fibro-vascular* cylinder, consisting of :—

1. Two diametrically opposite *xylem masses*, the oldest part of which is external. They consist of, only a few vessels.
2. Two *phloëm masses*, alternating with these. (These are not at all conspicuous.)
3. *Phloëm sheath* of thin-walled cells, outside the phloëm and xylem masses, and inside the bundle sheath.

N.B.—The growing point of the **root** has a single apical cell of the same form as that of the rhizome, and placed with its apex towards the tissue of the root. But it differs from that of the rhizome, in being covered by a *calyptra*, which is produced by the division of segments of the apical cell, cut off by division planes *parallel to its base.* Every fourth division plane is formed in this situation. This can be made out, by cutting longitudinal median sections of the apex of a young root, which has been hardened in alcohol. Imbedding is required, and considerable skill is necessary.

xii. Felicineæ — The Reproductive Organs of the Sporophore Generation.

i. Examine with the naked eye or with a pocket lens, the under surface of a fertile frond of **Nephrodium felix-mas** (male fern).

Observe :—

a. The "*veins*" on the pinnule of the leaf.

b. The elevated kidney-shaped bodies, lying in the course of the branches of the main vein of the pinnules. These are the *sori*, covered by their *indusia.*

ii. Dissect in glycerin, by means of needles and a simple microscope, one of the **sori.**

Make out :—

a. The kidney-shaped *indusium*, a thin membranous structure, attached by a sort of short stalk, springing from near its centre, to the leaf beneath. It covers over and protects the sorus.

b. The *sorus*, consisting of a globular mass of small bodies grouped together (*Sporangia*).

iii. Remove a **sorus,** from which the indusium has been dissected, and examine in glycerin with a 1-inch objective.

Observe :—

The *Sporangia*, forming the sorus. Each consists of a dark brown globular or elliptical structure, attached by a stalk to the leaf.

iv. Note carefully the structure of a **Sporangium.**

Observe :—

a. The *stalk* consisting, usually, of three rows of cells.

b. The *body* of the sporangium, consisting of a capsule or sac, somewhat compressed, so as to have the form of a bi-convex lens.

c. The body of the sporangium has a definite wall, consisting of a single layer of flattened cells, except at the margin. (This can be well seen in one, the sac of which has burst.)

d. The *annulus.* A ring of cells at the margin of the sporange. The cells composing it, have thick dark brown cell walls.

e. In a sporangium which has burst, note the transverse rupture in the thin part of the wall, and the straightened out annulus. (It is the straightening of the annulus, that causes the bursting of the sporange, when ripe.)

f. The annulus is *incomplete* at the base of the body of the sporange, *i.e.*, does not extend completely round at the base.

v. Cut sections through the **sori,** and examine with a low power.

Observe :—

a. The attachment of the indusium to a vein of the leaf, and its spreading out over the sporangia.

b. The attachment of the stalks of the sporangia to the vein of the leaf, in the angle between the stalk of the indusium and the leaf.

vi. Examine, with a pocket lens or simple microscope, in a drop of glycerin, the inferior surface of a leaflet of **Pteris.**

Observe :—

The elongated linear *sorus*, extending along the margins of the leaf, and covered by an *indusium* formed by the inflected edge of the leaflet.

vii. Examine in the same way, the under surface of the leaf of **Polypodium vulgare.**

Observe :—

The globular *sori*, attached in the course of a small "vein," and note, the entire *absence* of indusium.

viii. Examine in the same way, the under surface of the leaf of **Scolopendrium vulgare.**

Observe :—

a. In a young leaf, the white linear structures in the course of a "vein." These correspond to the young sori, covered by the young indusium.

b. In an older one, the very distinct raised linear *sori*, of brown colour, with the membranous *indusia*, bounding them laterally as raised membranes.

ix. Cut thin sections through a sorus of the **Scolopendrium,** and examine with a high power.

Observe :—

a. The same characters of the sporangia as seen in the Male Fern.

b. The *spores*—brown, unicellular, with a thick wall, roughly triangular, and having numerous external bands and knobs of thickening. They contain protoplasm.

x. Examine the **spores** of any other Fern.

Note :—

a. The same characters as in Scolopendrium.
b. All the spores in each species are alike (*Isosporous*).

xiii. Felicineæ—Oophore Generation.

The oophore individual, in the case of the Fern, is distinct from the sporophore, except during the early life of the sporophore produced from the oospore of the oophore individual. Of the two generations or stages in the life history, the sporophore is by far the more conspicuous, whilst the oophore partakes only of the character of a small thallus, and has no distinction into stem, root and leaf. To obtain specimens of the oophore, which usually receives the name of **Prothallus**, the spores of a Fern, not necessarily Pteris, should be taken, when ripe and dry, and sown in moist, rich earth in a shallow vessel, and covered over with a bell-glass. They must be kept moist and warm, for about a month or more, by which time, the surface of the earth is found to be covered with small green bodies.

i. Take a **prothallus** and examine it in water, with its lower surface uppermost, either with a pocket lens or with a low power.

Observe :—

a. A green, flattened expansion, of varying size, having a rounded margin with a depression at one place, so as to give it a *reniform* outline. The growing point is at the depression.

b. At the extremity opposite to the depression, are numerous brown root-hairs or *rhizoids*. These also are seen springing from the lower surface.

c. It is composed of a single layer of thin-walled chlorophyll-containing cells, except at one part, near to the growing apex, where the substance of the prothallus is several layers of cells in thickness. This is the *cushion.*

d. Note the *absence* of any definite apical cell.

e. The *reproductive organs.* These take the form of :—

1. Hemispherical outgrowths from the lower surface of the prothallus, particularly seen towards the posterior part of the prothallus, amongst the root-hairs. These are *Antheridia*, or male organs.

2. Flask-shaped structures, found on the under surface of the cushion, nearer to the apex than the Antheridia. Only the long cylindrical *necks* of these flask-like bodies are seen above the surface, the larger swollen part being imbedded in the substance of the cushion. They are the *Archegonia*, or female organs.

   Note, therefore, that each prothallus is *hermaphrodite.*

ii. Examine the **reproductive organs** carefully, with a low power.

Observe :—

a. In the *Antheridia.*

1. Hemispherical form.
2. *Wall*, consisting of a single layer of flattened cells.
3. Through the wall, are to be seen the *contents*, consisting of a few small round colourless cells—*mother cells of antherozooids.*

b. In the *Archegonia.*

1. The *wall* of the neck, consisting of *four* rows of cells, seen clearly if the organ happen to be vertical.
2. These surround a very few *canal cells* (one or two).
3. The *ventral portion,* swollen and globular, imbedded in the tissue of the cushion, and indistinctly seen on focusing down.

iii. Take some **prothallia,** which have been hardened in alcohol. Hold between two layers of elder pith, or imbed in wax. Cut a series of transverse sections, and examine all of them. Sections near the summit will show the archegonia, those near the base the antheridia. Having found sections showing the structures required, examine carefully with a high power in glycerin.

Observe :—

a. *Archegonia.*

1. *Wall of neck*, *four* rows of cells.
2. *Canal cells*, two in number. These will not be seen in old specimens, as they then become transformed into mucilage, and so open up the *neck-canal.*

3. The large central *oosphere*, of a spherical form, lying in the tissue of the cushion, beneath the canal cells.

4. The *tissue of the cushion*, surrounding this cell, which has no definite wall like that of the neck.

b. Antheridia.

1. *Outer wall*, thin, one layer of cells thick. Cells are flattened, and have a few chlorophyll grains in them.

2. *Contents.* These vary according to the age of the antheridium, usually a few small round *mother cells.* In younger ones, only a central mass of protoplasm ; in older cases, the coiled up antherozooids may be seen in the mother cells.

iv. If some fresh ripe **prothallia** are taken, in which the antheridia have burst, you may find swimming in the water some **Antherozooids.** Examine with a high power.

Observe :—

They consist of small, spirally coiled bodies with a thickened *head*, tapering into a *body* (coiled) and terminated by two *cilia*, which can be seen if their action is sluggish. Sometimes, a globular mass is found attached to the head of the antherozooids. This is some of the protoplasm of the mother cell, not used in the development of the antherozooid.

v. Examine some **old prothallia** in which the oosphere has been fertilized, and a young sporophore has begun to be produced.

Observe :—

a. The *primary root* of the young sporophore.

b. The single elongated *primary leaf*, at the base of which lies :—

c. The young *primary stem.*

d. The young sporophore is attached to the prothallus by a lateral expansion called the *foot.*

PART III.

PHANEROGAMIA—GYMNOSPERMIA.

i. Pinus Sylvestris—External Characters—The Stem.

i. Examine a branch of the **Pinus Sylvestris.** Begin by observing the younger parts at its summit, and work downwards.

Observe :—

a. The *terminal bud*, of brown colour, owing to the dark *scale leaves* which cover it. Around it, are three or four *lateral buds.*

b. The *stem* of the present year's growth, consisting of an axis, which is softer and more flexible than the older part of the stem. On it, note :—

c. The *scale leaves*, or rather the remains of the scale leaves (belonging to the bud produced at the end of the *previous* year's growth). They are brown in colour.

d. Throughout the extent of the present year's stem, note the *very short* branches, in the *axils* of the remains of the scale leaves. Each of these short axes or stems bears two long thick green *acicular foliage leaves.* They are *sessile*, and at their bases are found numerous brown membranous scale leaves. These short axes are of very limited growth.

e. Near the apex, the lateral buds lie in the axils of other brown scale leaves. They occupy similar positions near the summit, as the short leaf-bearing axes, lower down. Their growth is not limited; they are the rudiments of the *future* year's growth.

f. The *foliage leaves.* Compare them with the scale leaves on the buds and on the main axis.

g. The *reproductive organs.* Of these, there are two kinds, "male" and "female," on the same plant (monoecious).

1. The "male" organs, in an early stage of development, appear as *inflorescences,* in the same position on some branches as the terminal bud. They have the same appearance as the ordinary terminal bud.
2. The "female" organs appear as small, green or brownish *cones,* close to the terminal bud or "male" inflorescence. Each such cone is a *flower* (not an inflorescence, cf. "male" organ), and consists of a stalk, bearing brown scale leaves, and an upper globular part, marked into numerous quadrilateral areas, each corresponding to a *carpellary scale.*

h. Each axis of the present year's growth, traced downwards, joins the axis of previous year's growth at about the same spot as the other axes of the present year's growth, forming *pseudowhorls.*

i. The increment of growth of last year presents the same arrangement with respect to the growth of the year next before it, as the growth of the present year does (*i.e.*, arrangement in pseudowhorls).

k. As you pass lower and lower down the branch, the stem becomes larger, harder, and more lignified. The short foliage axes fall off with their acicular leaves, and scars mark their position.

l. The large green "*female*" *cones* at the summit (one or two together) of the growth of the year next before the present.

m. The large brown *lignified* "female" cones, borne in a similar position on the older parts of the stem.

ii. Cut a **terminal bud** longitudinally down its centre. In the section,

Observe :—

a. The *axis* or young stem, bearing :—

b. *Scale leaves,* in whose axils are :—

c. Minute *buds.*

iii. Cut a transverse section of a very **young stem,** such as that in the centre of a terminal bud. Examine in glycerin with a low power.

a. The *epidermis.*

b. The *fibro-vascular bundles*, forming a ring. In each, note :—

1. The *primary phloëm*, towards the periphery.
2. The *primary xylem*, near the centre.

N.B.—To make these more clear, stain in Schultz' solution.

3. The *cambium*, between 2 and 3.

c. The *fundamental tissue*, consisting of :—

1. The pith or *medulla*, within the ring of fibro-vascular bundles.
2. The *cortex*, outside the fibro-vascular bundles.
3. The *primary medullary rays*, lying between the bundles, and connecting together 1 and 2.

iv. Cut thin transverse sections of a stem of the **present year's growth.** Mount in glycerin, and examine with a low power.

Observe :—

a. The *epidermis*, the cells of which, have a definite outer *cuticle.*

b. The *cortex*, consisting of :—

1. *Parenchyma*, made up of large cells containing chlorophyll.
2. *Resin passages* in it.
3. *Cork tissue* and a *cork cambium* beneath it, near the periphery.
4. *Sclerenchyma*, lying in isolated masses beneath the epidermis.

c. The *fibro-vascular system*, forming a complete ring due to the completion of the cambium ring by the development of *interfascicular cambium* in the primary medullary rays, and the subsequent production from it, of secondary xylem and phloëm, and consisting of (in order from without inwards) :—

1. *Phloëm.* The primary and secondary phloëm are indistinguishable from each other.

2. The *cambium-ring* (Cf. the young stem)
3. *Secondary xylem*, forming the greater part of the radial extent of the section, consisting of numerous small rectangular areas (sections of the *tracheïdes*) marked off by the walls of the tracheïdes. The secondary xylem has a general radiating appearance, due to the regular radial arrangement of the elements composing it.
4. The *primary xylem*, consisting of convexities projecting from the inner edge of the secondary xylem into the central tissue. The primary xylem masses are often spoken of as the *medullary sheath*; and the oldest part (the most internal) of the primary xylem is called the *protoxylem*.

d. The *medulla*, consisting of parenchymatous cells, occupying the centre of the section. Similar cells are to be traced as wedge-like masses between the projecting primary xylem masses. These mark the position of the original primary medullary rays.

v. Stain a similar section with Schultz' solution.

Observe :—

a. The yellow colour of the *cuticle*.

b. Blue colour of the cell walls of the *cortical fundamental tissue*.

c. Yellow colour of the *cork tissue*.

d. Blue colour of the *phloëm*.

e. Yellow-brown colour of the *xylem*.

f. Blue colour of the *medulla*.

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ii. Pinus Sylvestris—The Stem (CONTINUED).

i. Examine a very thin transverse section of a **present year's stem** with a high power.

Observe :—

In the **xylem**.

a. The *tracheïdes*, appearing in transverse section, as more or less quadrilateral cells arranged in radial rows.

Note :—

1. The *cell walls*, consisting of a *common cell wall* or *middle lamella*, and the thickened portion special to each cell, distinguishable again into two layers.
2. The *bordered pits*, appearing as lenticular-shaped spaces in the thickened cell wall. In some of them, note the narrow opening of the pit cavity into the interior of the tracheïde. Unless your section happen to have passed through this opening, the bordered pit merely appears as a closed lenticular space in the cell wall. They are seen chiefly in the radial walls, and each pit-cavity is traversed by the common cell-wall, usually deflected to one side, so that the pits are, as a rule, not perforated.
3. Absence of protoplasm. The elements of the secondary xylem are above called *tracheïdes*, but this term should strictly be reserved for those prosenchymatous cells, which, not being true vessels, are yet in communication by *perforations in their side walls.*

b. The *secondary medullary rays*, consisting of single rows of cells, elongated in a radial direction, lying amongst the radial rows of tracheïdes. They do not extend throughout the whole radial extent of the wood.

Note :—

1. Thin *cell walls*, consisting only of the middle lamella.
2. Absence of thickening of the adjacent radial wall of the tracheïdes.
3. Presence of protoplasm.

c. *Resin ducts*, consisting of round spaces surrounded by a layer of small, thin-walled parenchymatous cells of a dark colour.

In the **cambium.**

a. Thin-walled quadrilateral cells, somewhat elongated *tangentially*, arranged in radial rows. They contain protoplasm and nucleus. These are *meristematic* cells, which divide tangentially and produce xylem and phloëm.

b. The radial rows of cambium cells can be traced into continuity with the rows of tracheïdes.

In the **phloëm.**

a. The *medullary rays,* dividing the phloëm into rectangular areas.

b. *Phloëm vessels* or sieve tubes, arranged in radial rows.

c. *Phloëm parenchyma,* forming a few large cells amongst the vessels.

d. Continuity of the radial rows with the radial rows of cambium cells.

e. The elements of the phloëm are radially compressed and otherwise distorted.

In the **cortex.**

a. The cork tissue or *periderm.*

b. The cork-cambium or *phellogen* (see *General Morphology,* page 39.

ii. Cut thin transverse sections of a **four-year-old** stem of **Pinus.** Examine with a low power.

Observe :—

a. The *medulla.*

b. The *xylem,* occupying the greater part of the radial extent of the section. Note that it is made up of four broad bands of tissue, marked off from each other by sharp lines, formed by the difference in the size of the tracheïdes of the autumn and spring wood, and in the thickness of their walls. These are the *annual rings.* Each corresponds to a year's growth.

c. The *cambium.*

d. The *phloëm,* which is thicker than in a one-year-old stem, but does not present any annual rings. The tissues composing it are much compressed and distorted. It is much darker than the xylem.

e. *Cortical fundamental tissue and cork.* In a stem of this age, the tissues outside the xylem are often spoken of as "*cortex.*"

iii. Cut thin longitudinal *radial* sections of a stem of **Pinus** (two or three years old). Examine with a high power

Observe :—

a. The parenchymatous *medulla.*

b. The *primary xylem,* consisting of elongated elements, having spiral, annular, reticulated or irregular thickenings in their walls. Scattered amongst these, are some elements having spiral thickenings mixed with bordered pits. Some of them are true tracheïdes.

c. *Secondary xylem*, consisting of tracheïdes, prosenchymatous in form, with thickened walls, and presenting *bordered pits*. The bordered pits appear as two concentric rings, and are seen on surface view of the *radial* walls of the tracheïdes. Compare their appearances in longitudinal sections with transverse sections and obtain a clear knowledge of their structure.

d. *Secondary medullary rays*, consisting of small cells with granular dark contents, lying in radial rows across the tracheïdes. They extend much further radially than they do in height. Where the medullary rays lie, the pits in the radial walls of the tracheïdes are very large and wide.

e. The *annual rings*.

f. A *resin passage* may have been included in the section, and is seen lying in the xylem amongst the tracheïdes.

g. The *cambium* layer, consisting of thin-walled cells elongated longitudinally and compressed radially. They lie in radial rows, and the radial rows of cells of the secondary medullary rays may be traced into continuity with them.

h. The *phloëm*, consisting of vessels (*sieve tubes*) intermixed with parenchymatous cells. The sieve plates in the sieve tubes of Pinus are not easy to demonstrate. (See *Helianthus* and *Sambucus*.) Medullary rays, similar to those of the xylem, are seen in the phloëm. The secondary and primary phloëm cannot easily be distinguished.

i. *Cortical tissue* and *epidermis*.

iv. Cut thin longitudinal *tangential* sections of stem of **Pinus.** Mount in glycerin and examine with a high power.

Observe :—

a. The section does *not* include *medulla*.

b. The *xylem* (only secondary xylem is seen). It consists of prosenchymatous cells, presenting bordered pits. These, however, have a different appearance to that seen in longitudinal radial sections. Instead of two concentric rings, they now have the appearance of lenticular spaces in the *radial* walls of the tracheïdes and are traversed by the common cell wall. They thus have similar appearances to those seen in transverse sections.

c. The *secondary medullary rays.* In tangential sections, these appear as rows of cells of small height in the stem, and one layer of cells in thickness. Sometimes, a medullary ray consists only of one cell, at other times, of two or three or more. Each such row of cells lies amongst the tracheïdes, and has the appearance of a bi-convex lens, being broader in the middle of the row than at the extremities.

d. The *cambium*, composed of thin-walled cells with protoplasm and nucleus.

e. The *phloëm*, made up chiefly of thin-walled tissue, *sieve tubes* and *parenchymatous* cells. Secondary medullary rays are also seen, having the same structure as those of the xylem.

f. A *resin passage* may have been cut in longitudinal section in the xylem.

g. The *cortical fundamental tissue* and *epidermis.*

iii. Pinus Sylvestris—The Leaf.

i. Examine with the naked eye, one of the short foliage shoots of **Pinus.**

Observe :—

a. The very short stem, attached to the main axis of the plant, and terminated by :—

b. *Two long green foliage leaves*, the bases of which are surrounded by a sort of sheath of brown dry scales.

c. The form of the foliage leaves—acicular, tough, ribbed longitudinally, hemispherical in section on their outer surfaces, flat on the inner ones. The two flat surfaces of the two leaves applied together.

ii. Cut thin transverse sections of a leaf, and having mounted in glycerin, examine with a low power.

Observe :—

a. Hemispherical form of the section, the flat surface being regarded as the upper side.

b. *Epidermis*, a single layer of cells at the surface.

c. *Hypodermis*, a stratum of cells, two or three layers in thickness, lying just beneath the epidermis, and having a bright appearance, and thick cell walls. It is interrupted at intervals.

d. The broad band of *mesophyll*, consisting of several layers of chlorophyll-containing cells, forming the general parenchyma of the leaf.

e. The internal mass of fundamental tissue, consisting of cells not containing chlorophyll, and having a bright appearance.

f. The two *fibro-vascular bundles*, lying in the middle of this central mass of colourless tissue.

g. *Resin ducts*, lying in the peripheral parts of the mesophyll.

iii. Examine your thinnest section with a high power.

Observe :—

a. The *epidermal* cells have a very thick and distinct outer cuticle, in which two layers can easily be distinguished, and which exhibits stratification.

b. The *stomata*, openings leading deeply into the tissue below the surface, and each surrounded by two thick-walled *guard cells*, placed considerably below the surface.

c. The large *intercellular spaces*, into which the stomata open.

d. The thick-walled cells of the *hypodermis*, consisting of sclerenchymatous tissue, of bright appearance, and presenting a distinction into two layers of cell wall; simple pits may be seen in this tissue. It does not form a continuous band, but is interrupted at intervals in the positions of the stomata.

e. The chlorophyll-containing *mesophyll*, consisting of thin-walled parenchymatous cells, whose cell walls present a peculiar infolding. The infolding of the cell wall is best seen on cutting thin sections of leaves which have been kept in alcohol.

f. *Resin ducts*, which are intercellular spaces surrounded by a single layer of thin-walled cells with brown granular contents.

g. Rings of *sclerenchyma*, like that of the hypodermis, surrounding the layer of cells of the resin duct.

h. The colourless fundamental tissue in the centre of the section, consisting of parenchymatous cells with thin walls and protoplasmic contents, intermixed with a few cells of the same form, having no contents, and presenting appearances like bordered pits, but seemingly not perforated and merely consisting of lenticular spaces in the cell walls.

i. *Fibro-vascular bundles*, consisting of rows of xylem and phloëm cells, the former somewhat thickened, the latter thin walled. Xylem is directed towards the flat side, or upper surface of the leaf.

v. Stain a section with Schultz' solution, and note the results.

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iv. Pinus Sylvestris—The Root.

Cut thin transverse sections of the **root** of a young seedling of **Pinus.** Mount in glycerin.

Observe :—

a. *Absence* of any definite *epidermis.*

b. Cortical *fundamental tissue.*

c. The single layer of cells of the *endodermis* or bundle sheath.

d. The *pericambium* within this, and composed of several layers of cells.

e. *Four* or *five* masses of **xylem,** arranged radially round the centre. Each is V-shaped, and has the apex directed inwards.

f. Indistinctly seen, are four or five **phloëm** masses abutting on the pericambium, and alternating with the xylem masses.

g. The central **medulla,** in the middle of the fibro-vascular cylinder.

h. The small-celled *conjunctive tissue,* filling up the spaces in the fibro-vascular cylinder, between the xylem and phloëm masses.

i. A *resin duct,* lying in the pericambium, opposite to each xylem mass.

ii. Cut thin transverse sections of a **lateral root** of a Pinus tree. Clear with potash, and mount in glycerin. Examine with a low power.

Observe :—

a. Outer brown dried, withered *cortex.*

b. *Cork tissue*, with a cork cambium internal to it.

c. The *phloëm*, forming a narrow, irregular ring.

d. The *cambium*, forming a complete ring of meristematic tissue, as in the stem, and lying just beneath the phloëm. This tissue has been formed by cell division taking place in the *conjunctive* tissue of the fibro-vascular cylinder, and by it there has been produced :—

e. The *secondary xylem*, consisting of a broad band of tissue passing completely round the root. It presents the same general appearance as the secondary xylem of the stem, and has secondary medullary rays as well as annual rings, as in the stem.

f. The *primary xylem*, in the form of four or five little masses projecting from the secondary xylem.

g. The central *medulla.*

iii. By taking sections of roots at various ages, it can be shown that :—

a. The *cambium* is formed from the conjunctive tissue of the fibro-vascular cylinder of the young root.

b. The *cork tissue* is formed from a meristem, which arises in the peripheral parts of the pericambium of the young root.

c. *Secondary lateral roots* take origin from the pericambium, opposite to the primary xylem masses of the young root.

iv. Imbed in wax, or hold between two layers of elder pith, the **apex** of the root of a young seedling of **Pinus** which has been hardened in alcohol, and cut longitudinal sections, or cut longitudinal sections of the **embryo** within the seed. Mount in glycerin, or stain in logwood, and then clear in clove oil, and mount in Canada balsam.

Observe :—

a. The well-marked central cylinder of *plerome*, terminating in a rounded summit.

- *b.* The *periblem*, forming a hollow cylinder surrounding the central plerome. Trace this upwards and find that it is continuous with :—
- *c.* The *calyptra*, the cells of which at the summit, form a cone and are loosely arranged.
- *d.* The absence of any definite *dermatogen.*
- *e.* Under a high power, the layer of cells of the deeper part of the periblem covering the summit of the plerome is in an active state of growth, and forms an *initial layer*, from which there arise the calyptra and the tissue of the periblem.

v. In thin sections of the apex of the Pinus root, study the stages in cell division according to the directions at page 45.

V. Pinus Sylvestris — The Organs of Reproduction.

i. Take a "**male**" cone or **inflorescence** (See page 88); and cut it longitudinally down the centre (it is better if it has been kept in spirit for some time).

Observe :—

- *a.* The *main axis* or stem of the inflorescence (*rhachis*).
- *b.* The brown *scale leaves*, in the axils of which are seen :—
- *c.* *Lateral buds.*—Those near the apex are ordinary young foliage shoots or axes, and bear rudiments of two foliage leaves. Those lower down are not ordinary foliage shoots, but are young "male" *flowers*. Examine one of these carefully, dissecting it with needles; make out :—
    1. Its *axis*, bearing :—
    2. Numerous very small scales, which are the pollen bearing leaves or *stamens*.

ii. Remove one of the scale like **stamens**, mount in glycerin and examine with a low power.

Observe :—

- *a.* The very short broad stalk or *filament* of the stamen.
- *b.* The *anther*, borne at the summit of the filament, and consisting of a flattened scale bearing on its inferior face, two oval swellings or sacs. These are the *pollen sacs*, and are morphologically equivalent to the *microsporangia* of the higher Vascular Cryptogamia.

iii. Rupture the **pollen-sacs** of a stamen, either by needles or by pressing on the cover glass.

Observe :—

The *pollen grains*, escaping from the rupture in the pollen sac.

iv. Put on your high power, and examine the **pollen-grains** (which are morphologically equivalent to the *microspores* of the Vascular Cryptogamia).

Observe :—

a. The *body* of the pollen grain, consisting of :—

1. The *cell wall*, distinguishable into two layers, *extine* and *intine*.
2. The *protoplasm*.
3. The *vegetative cell*, consisting of a small part of the contents of the grain marked off from the rest by a crescentic cell wall. (This cell may not be seen in pollen grains so young as these, but are well seen in the ripe pollen grains).

b. The bladder-like outgrowths or *wings* of the pollen grain, made up of expansions of the extine.

v. Examine a fertile shoot of **Pinus**, when the parts of the young inflorescence have expanded. (This can only be obtained in the early summer).

Observe :—

a. The *main axis*, *i.e.*, the expanded axis of the bud, bearing :—

b. *Lateral foliage shoots*, at its summit.

c. The *floral axes*, lower down. Each of these is the expanded axis of a young flower of the cone, and each bears :—

d. The *stamens*. On shaking the shoot there can be seen :—

e. The dust-like *pollen grains*.

vi. Mount some of the dust-like ripe **pollen** in glycerin.

Observe :—

The points described under iv., *a* and *b*.

N.B.—It is only the main body of the pollen grains tha takes any part in the subsequent formation of the *pollen tube*. The vegetative cell does not enter into this process. It is morphologically the *male prothallus* of a Vascular Cryptogam. The wings simply serve the function of facilitating the *scattering* of the pollen.

vii. Examine one of the small "**female**" **cones**, described at page 88, cutting longitudinally down its centre.

In the section,

Observe :—

a. The main central *axis*, bearing :—

b. The large *carpellary scales*, the outer surfaces of which correspond to the quadrilateral areas seen on the cone. At the base of each of these, is seen :—

c. A much smaller *scale*, in whose axil the large carpellary scale seems to be attached. The larger scale is really an outgrowth from the upper surface of the small scale, and is regarded as a sort of enormously developed *placenta*.

viii. Dissect off one of the **carpellary scales.** On its under surface,

Observe :—

The *ovules*. Note that there are two of these near the base of the scale; that the apex of each is directed downwards, towards the base of the scale (*anatropous*).

ix. Cut longitudinal sections of a "**female**" **cone.** Mount in glycerin, examining several sections.

Observe :—The *ovules*. In each, note :

1. The single *integument*.
2. The *micropyle*, bounded by the extremity of the integument.

3. The *nucellus*, or central mass of cells, in which lies—

4. The *embryo-sac*, a single cell much larger than the rest of the nucellus.

N.B.—The ovule, morphologically, is equivalent to the *macrosporangium*, and the embryo-sac to the *macrospore* of the Vascular Cryptogamia.

x. Cut similar sections of the **older "female" cone,** described at page 88, mount in glycerin.

Observe :—

a. The characters described in ix.

b. In the embryo-sac, note the *endosperm*, consisting of a mass of parenchymatous cells.

c. The *corpuscula*, one or two masses of cells, at the summit of the endosperm. Each consists of—

1. The *neck*, surrounded by a few small cells.

2. The *oosphere*, a single large cell just beneath the neck cells.

N.B.—The endosperm is equivalent to the *female prothallus*, the corpusculum to the *archegonium*, and the oosphere to the *oosphere* of the Vascular Cryptogamia.

xi. Examine the **"female" cones,** described at page 88.

Observe :—

a. The hard dry remains of the *carpellary scales.*
b. The *seeds* (winged).

xii. Dissect out a **seed,** and examine it.

Observe :—

a. The *testa* (the dry integument).

b. The *micropyle.*

c. The large mass of *endosperm*, containing—

d The *embryo.*

xiii. Dissect out the **embryos** with needles, and examine in glycerin with a low power.

Observe :—

a. The *suspensor.*

b. The *radicle*, attached to the suspensor.

c. The *cotyledons*, several in number and surrounding—

d. The rudimentary *plumule.*

PART IV.

PHANEROGAMIA—ANGIOSPERMIA.

DIVISION A.—DICOTYLEDONS.

i. Helianthus — External Characters — Apical Region of Stem.

i. Examine a fairly well grown plant of **Helianthus** (sunflower), *i.e.*, just before flowering.

Observe :—

a. The *main axis* of the plant, consisting of :—

1. The *primary stem*, erect, cylindrical, tapering somewhat toward the apex, herbaceous, but firm and resistant, green, covered with short hairs.

2. The *primary root*, a continuation downwards of the primary stem, elongated, not so long as the primary stem, brown or yellowish in colour, not containing chlorophyll, tapering very much towards its extremity (tap root)—and much branched there.

b. The *foliage leaves*, borne laterally on the primary stem, simple, consisting of a leaf stalk or *petiole* and a large flat expanded *lamina* or blade. The lamina has a *cordate* or *ovate-lanceolate* form, with pointed extremity. In the lower part of the plant, *two* leaves are borne from the same level of the primary stem (*opposite*), higher up, one only at the same level (*alternate*). The surface of the leaf blade is hairy ; the petiole is grooved upon its upper surface.

c. *Lateral roots*, numerous, varying in size, borne more or less in rows upon the primary root, soft, delicate and slender towards their terminations. The lateral roots, borne from the upper and older part of the primary root, are larger and stouter than those borne nearer to the summit.

d. *Terminal bud* of the stem, at the summit of the primary axis, consisting, according to the age of the plant, either of the flattened extremity of the stem covered over and surrounded by numerous layers of leaves of varying size, or of an *inflorescence*, made up of numerous short axes crowded together, and each terminating in a flower or flower bud, and surrounded by several layers of leaves at the periphery. Such an inflorescence is called a "head" or *capitulum*.

e. *Lateral buds*, or *short branches* of the primary stem (according to the age of the plant). These are found in the axils of the leaves of the primary stem, particularly in the axils of the upper leaves. Each branch is terminated by a *bud*, or by an *inflorescence* similar to, though smaller than, that found at the apex of the primary stem.

f. The *nodes* and *internodes* of the primary stem, the latter longer in the older and lower parts of the stem.

ii. Cut thin longitudinal sections of the termination of the main stem, or of a lateral stem, before the formation of the flower has begun. Mount in glycerin and examine with a low power.

Observe :—

a. The entire *absence* of an apical cell.

b. The flattened disk-like termination of the stem, raised somewhat in the centre, *i.e.* the true summit.

c. *Leaves* in various stages of development at the peripheral parts of the disk, oldest and largest leaves most external, younger ones nearer to the apex. (*Acropetal succession*).

d. The general small-celled active meristem, occupying the extreme summit.

e. Slightly removed from the summit, the meristem is differentiated into certain layers, viz. :—

1. The *dermatogen*—a single layer of cells at the surface. This is the generating tissue of the epidermis. Traced downwards, it will be found to become continuous with the epidermal system to be presently described. Its cells divide only at right angles to the surface.

2. The *procambium*—consisting of dark-looking longitudinally-placed rows of cells. They are the generating cells which form the fibro-vascular bundles.

3. The central cellular cylinder, the generating tissue for the central part of the fundamental system; (2) and (3) may, for sake of comparison with the root (see page 121), be called together the *plerome*, as they represent this meristematic mass, seen in roots.

4. Between the dermatogen and the procambium lies the *periblem*, the generating tissue for the cortical part of the fundamental system.

iii. In the same sections, study the *development of leaves*.

Observe :—

a. That they arise as outgrowths of the dermatogen and periblem, and at first only consist of these parts.

b. Subsequently there forms in them a *procambium*, which becomes, later on, continuous with that of the stem.

iv. Study also the *development of hairs*.

Observe :—

That in all cases they take origin from the dermatogen or its product, the epidermis. They are not found at the extreme apex.

ii. Helianthus—The Stem.

i. Cut thin transverse sections of the young part of the **stem** of **Helianthus.** Mount in glycerin, and examine with a low power.

Observe :—

a. The *epidermis*, consisting of a single layer of cells completely covering the surface of the section, and giving origin here and there to—

b. *Hairs.* Note their attachment to the epidermal layer, but no deeper.

c. *Cortical* part of the *fundamental tissue*, consisting of—

1. The *hypodermis*—a band of tissue just beneath the epidermis, and made up of smaller cells than the rest of the fundamental tissue. The variety of parenchyma composing this tissue is *collenchyma* (the details of its structure will be seen on examining with a high power).

2. Ordinary thin-walled *parenchyma*, with small intercellular spaces, made up of cells considerably larger than those of the hypodermis.

3. The *bundle sheath*—a single layer of small thin-walled cells immediately surrounding the ring of fibro-vascular bundles. It is seen better on examining with a high power.

d. *Fibro-vascular bundles.* These are numerous wedge-shaped masses of tissue, separate from each other (in the *young* stem), and arranged in a ring.

e. The central part of the fundamental tissue known as the *medulla*, or pith, lying within the ring of fibro-vascular bundles, composed of ordinary thin-walled colourless parenchyma.

f. The *primary medullary rays*, composed of similar parenchyma to the pith, and forming radiating bands of tissue which connect together the peripheral cortex and the central medulla.

ii. Examine your thinnest section with a high power.

Observe :—

a. *Epidermis*—made up of a single continuous layer of somewhat flattened cells. The cell walls are particularly thickened in the outer layer, which forms a definite *cuticle* covering the external surface. These cells contain a little protoplasmic material, but no chlorophyll.

b. The *hairs*—continuous with the tissue of the epidermis, which at the point of attachment of the hairs forms a prominence. Each hair is broad below, but tapers to a point at its free extremity, and is made up of a single row of several cells.

c. The *hypodermis*—made up of collenchyma, *i.e.*, tissue in which the cells have walls particularly thickened at the angles at which two or more cells join. The beads of thickening have a bright refractive appearance, and sometimes present small slit-like intercellular spaces in their middle. The contents of the cells are protoplasm and chlorophyll, so that this band of tissue presents a darker appearance than the rest of the fundamental tissue.

d. The *tissue* of the *medulla*, *medullary rays*, and rest of the *cortex*, consists of ordinary thin-walled large parenchymatous cells with intercellular spaces, and very little colourless protoplasm. Note some resin ducts lying in the cortical fundamental tissue.

e. The *bundle sheath* or *endodermis*, consisting of a thin layer of very thin-walled cells. They are considerably smaller than the other cells of the fundamental tissue. Their contents are granular, and chiefly starch. This layer of cells can be traced continuously as a ring outside the fibro-vascular bundles. (*See* page 24.)

f. The *fibro-vascular bundles*. Each bundle is made up of *three* main parts, arranged in a radial series : the most external is *phloëm*, the most internal is *xylem*, and between these there lies a meristematic tissue or *cambium*. Examine each of these carefully, making out—

1. The *phloëm* or *bast*, consisting of two parts, **hard bast** and **soft bast.** The former lies most externally, and nearest to the bundle sheath,

and consists of several layers of cells, each cell small in section, having cell walls much thickened, bright and highly refractive in appearance, and with very little cell-contents. These are the phloëm or bast **fibres**, and in very young stems are not easily distinguishable from the phloëm parenchyma. The soft bast lies more internally and has a generally darker appearance. It is made up of thin-walled cells, possessing granular cell-contents. Some of the cells are large in section. These are the **sieve tubes** or **vessels** of the phloëm; but the greater number are small and form the phloëm **parenchyma.**

If the cells of the soft bast are traced inwards towards the deeper tissues, they are found to be arranged in radial rows, which in the deepest part of the phloëm become continuous with the rows of cambium cells.

2. The *cambium*, consisting of a narrow, rather misty, or finely granular-looking band, lying just internal to the soft bast. It consists of thin-walled cells containing protoplasm, arranged in radial rows, continuous on the one hand with the rows of phloëm cells, and on the other with the rows of xylem tissue. Each cell is flattened in its radial diameter, and elongated tangentially; they have sharp angles, and thus present the form of parallelograms in transverse sections. These cells are meristematic, and are in a constant state of division by tangential division planes.

3. The *xylem*, consisting of various cellular elements arranged in more or less radial rows. The large polyhedral or rounded spaces are sections of **vessels.** Each consists of a thickened cell wall, surrounding a central cavity from which the protoplasm has disappeared. The walls of the vessels nearest to the cambium are not so thick as the others. These are the younger vessels, and have pits in their walls. The older vessels (*protoxylem*), in the more internal parts of the xylem, are spiral vessels, and are smaller than the younger ones. Lying amongst the vessels, and particularly in the younger parts of the xylem, are rows of wood **fibres,** whose walls are considerably thickened (not so much in sections of very young stems). Scattered amongst these,

but particularly lying between the spiral vessels of the oldest parts of the xylem, are large numbers of small thin-walled cells with granular cell-contents. They form the xylem **parenchyma.** Carefully trace the radial rows of the elements of xylem and phloëm into the rows of cambium cells, and satisfy yourself that they are developed from the cambium.

N.B.—The parts of a fibro-vascular bundle may be tabulated thus :—

Phloëm	**Fibres**	*Hard bast.*
	Vessels (*sieve tubes*)	*Soft bast.*
	Parenchyma	
Cambium	= a *meristem.*	
Xylem	**Vessels** (*spiral*, *pitted*, &c.).	
	Parenchyma.	
	Fibres.	

iii. Cut thin transverse sections of an older stem of **Helianthus** (one about $\frac{1}{4}$—$\frac{1}{2}$-inch or more in diameter); mount in glycerin, and examine with a low and afterwards a high power.

Observe :—

a. The same general arrangement of tissues as in the young stem.

b. Bundle sheath less distinct—in fact, very difficult to trace.

c. The fibro-vascular bundles more distinct and larger than in the young stem.

d. The phloëm fibres very obvious, and their walls thicker than in young stems.

e. Wood fibres very distinct.

f. Fibro-vascular bundles are united together by bands of tissue extending *across the primary medullary rays.* These bands of tissue consist of :—

1. A *meristematic* tissue, continuous with the cambium of the fibro-vascular bundles. This meristem has been formed in the primary medullary rays by means of tangential divisions in their cells; and the meristem thus formed is called *inter-fascicular cambium*, and with the cambium of the bundles forms a complete ring of meristematic tissue.

2. A few elements lying internal to the interfascicular cambium, and continuous with the younger parts of the xylem. These are *interfascicular bands of xylem.*

N.B.—In the case of Helianthus, which is an *annual*, the cambium-ring, formed by the means stated above, gives rise only to a small amount of *secondary xylem* and *phloëm*, but in some other cases of dicotyledonous stems a large and very thick band of secondary xylem is produced. These two types of stems may be distinguished as the *herbaceous* (Helianthus) and *woody.* A type of the woody stem will be described in the sequel.

iii. Helianthus—The Stem (CONTINUED).

i. Cut thin longitudinal *radial* sections of an old stem of **Helianthus**; mount in glycerin, and examine with a low and high power.

Observe :—

a. The *epidermis*, consisting of cells having their long diameters placed longitudinally, and their short diameters radially. They form a single layer at the surface.

b. The *hairs*—consisting each of a single row of cells attached by a broad base to the epidermis, which is raised at these spots.

c. The *cortical fundamental tissue*, distinguished into two layers of cells—

1. The outer, *collenchyma*, consisting of cells elongated in a longitudinal direction, and having thickenings, particularly in their longitudinal walls. The cells contain chlorophyll grains, and a protuberance of these cells is formed where the hairs leave the epidermis.

2. The inner, ordinary parenchymatous cells, having thin cell walls, with intercellular spaces and very little colourless cell-contents.

N.B.—The bundle sheath cannot usually be distinguished.

d. The central *medulla* of ordinary thin-walled parenchymatous cells.

e. The *fibro-vascular bundle.* In the bundle the following layers and forms of cells can be seen from without inwards :—

1. The *phloëm fibres*, or hard bast, forming a thick band of tissue, several layers of cells in thickness. The cells are prosenchymatous, their walls are pitted and thickened, and they do not contain protoplasm. In specimens which have not been kept in spirit, they often are found to contain large air-bubbles, which obscure their structure.

2. Several layers of thin-walled cells with granular protoplasmic contents. These cells are considerably shorter in their radial diameters than in their longitudinal ones; as the cells of the cambium have a similar form, these are often called *cambiform* cells.

3. *Sieve tubes.* These are found scattered amongst the cambiform cells of the soft bast. They should be carefully studied in both longitudinal and transverse sections. As seen in transverse sections, they appear as large thin-walled cells lying amongst the cambiform cells of the phloëm. Occasionally, in one of these large cells there is seen a *sieve plate* (the section happens to have passed near it). It has the form of a transverse disk with a dotted appearance (due to the perforations in it). Closely adjacent to the sieve tubes, and appearing as if merely segmented off from them, there are two smaller cells (best seen in those in which the sieve plates are visible). These are the *companion* or *sister cells* of the sieve tubes. In longitudinal sections, the sieve tubes appear as long rows of elongated cells, separated from each other by transverse or oblique septa, and the two elongated companion or sister cells may occasionally be made out. The cells composing the sieve tubes have the same general form as the cambiform cells, but are larger and are swollen at the positions of the transverse septa. The walls of the cells of the sieve tubes are thin, except the transverse walls, which are somewhat thickened, but in such a manner as to leave unthickened spots, where actual perforations are found. These transverse walls are the sieve plates. The protoplasm of the sieve tubes is

finely granular, and at the junction of the cells composing the tubes it swells out into a broad mass. Between the broad extremities of the protoplasm, in adjacent cells of the sieve tubes, there pass a number of fine protoplasmic filaments, traversing the small canals in the sieve plates, and so placing the contents of the cells of the tube in direct organic continuity. The sieve plates are often obscured by a material called *callus*. All these points are best demonstrated by taking a very thin section, treating it first with dilute potash, which dissolves the callus and leaves the sieve plate untouched. Then stain with iodine or eosin or Spiller's purple (which stain the protoplasm), and examine with a high power.

4. *Cambium*, consisting of thin-walled cells with protoplasmic contents. They are elongated, and narrow in their radial diameters.
5. *Xylem vessels.* Those nearest to the cambium are of the *pitted* kind. The pits are regularly arranged and bordered. Where the side walls of the pitted vessels are cut longitudinally, there is found a beaded appearance, due to the regular pits with thickening between them. The pits are not perforated. The remains of the transverse septa, which originally separated the cells composing the pitted vessels, may also be seen. The older vessels are almost all of the *spiral* variety, the band of thickening making either close spiral turns or loosely arranged turns. One or two vessels with irregular or *reticulated* thickening may be seen, and occasionally a vessel with a regular series of *annular* thickenings is found in the older parts of the xylem.
6. *Xylem fibres* are found in layers of two or three between the vessels in the younger part of the xylem. They are prosenchymatous, and have thickened walls.
7. Thin-walled *xylem parenchyma*, particularly found amongst the spiral vessels in the older parts of the xylem.

ii. In longitudinal *tangential* sections varying appearances are found, according to what parts of the bundles and how many bundles, the sections happen to pass through. These do not need a separate description.

iv. The Woody Type of Stem—Sambucus.

i. Examine with the naked eye a shoot of **Sambucus nigra** of the present year's growth.

Observe :—

a. Green or brownish in colour.

b. Hard and resistant in consistency.

c. Ribbed.

d. Glabrous.

e. Certain raised oval areas of a brown colour, scattered over the surface (*lenticels*).

ii. Cut thin transverse sections of the **present year's stem**; mount in glycerin, and examine with a low power.

Observe :—

a. *Epidermis.* The single layer of cells at the surface. Note the outer thickened stratified cell wall or *cuticle*.

b. The *stomata.* Usually the position of these is marked by a raising of the epidermis.

c. The *cork layer.* Two or three layers of cubical or oblong thin-walled cells, whose walls have been cuticularised. Beneath the stomata, note the interruption of the cork tissue. In these situations, there is a rising up of the surface, and the cells beneath the stomata are small and rounded, loosely arranged, and of a brown colour. These are the young lenticels.

d. The *lenticels.* Here the epidermis is ruptured and the margins are raised. The rupture is filled by a large number of thin-walled, brown, loosely-arranged cells. The epidermis has given way in the positions of the stomata, and the lenticels perform the functions of stomata (Cf. *c*).

e. The *cork cambium* or *phellogen.* This is a narrow, complete band of formative tissue, extending round the stem beneath the cork tissue. It consists of oblong cells elongated tangentially and flattened radially. By it the cork is produced, and also the loose tissue of the lenticels. It is better seen with a high power.

f. *Cortical fundamental tissue*, consisting of two bands of cells.

1. An outer layer, many cells in thickness, of *collenchyma*, with dark granular cell-contents.
2. An inner stratum of cells, also several layers in thickness, consisting of ordinary *parenchyma*, containing abundant granular protoplasm with numerous small starch grains.

g. *Hard bast*, consisting of isolated groups of thick-walled, bright-looking cells. The groups form an interrupted ring.

h. *Soft bast*, forming a complete ring of dark-looking tissue, made up of thin-walled cells with dark granular protoplasmic contents.

i. *Cambium.* A narrow but complete ring of thin-walled cells having the same general characters as the cambium in Helianthus.

j. The *secondary xylem.* A broad band of hard tissue composed of vessels and wood fibres, the former appearing as large spaces—some with dark brown, clear contents,—the latter as narrow smaller spaces, with thickened bright cell walls. Note the general radiating appearance of this layer and the radiating bands of darker-looking cells (*secondary medullary rays*).

k. The *primary xylem*, consisting of wedge shaped groups of cells, projecting from the inner side of the secondary xylem at intervals around the stem. They form an interrupted ring, and give a sort of crenated margin to the inner side of the xylem band. Note that they are found in the *same radial line* with the isolated masses of hard bast. These mark the original xylem and phloëm elements of the *primary* fibro-vascular system, *i.e.*, that existing before the *complete* cambium ring was formed, and the production of secondary xylem and phloëm took place.

l. The central *medulla*, or pith, of ordinary parenchymatous fundamental tissue.

iii Examine your thinnest section with a high power, and make out more carefully the characters of the cells composing the various layers.

Observe :—

a. Cells of epidermis contain finely granular protoplasm.

b. Cork cells have no protoplasmic contents.

c. The phellogen cells are elongated tangentially and contain protoplasm. Trace the gradual transition of the radial rows of phellogen cells into the radial rows of cork cells.

d. The collenchyma cells contain protoplasm.

e. The form of the *cambium* cells.

f. The radial rows of parenchymatous cells which form the secondary medullary rays. They have very dark granular contents, and are elongated radially.

g. The very thick walls of the wood fibres and of the hard bast. Note their narrow cavities, and the distinction into common and thickened part of the cell wall.

h. The regular radial arrangement of the wood fibres. Trace them into the radial rows of cambium cells.

Stain a section in Schultz' solution, and note the results.

Cut thin longitudinal *radial* sections of the one-year-old stem of **Sambucus**. Examine in glycerin with a low and then with a high power.

Observe :—

a. The *epidermis.*

b. The *cork tissue*, consisting of thin-walled nearly cubical cells without protoplasm.

c. The *cork cambium*, made up of thin-walled cells, elongated, narrow in their radial diameters, and containing protoplasm.

d. The *collenchyma*, composed of elongated cells, oblong in form, with thin transverse walls, and bright, highly refractive, thickened longitudinal ones.

e. General ordinary cortical parenchyma, with thin walls and plentiful granular protoplasm.

f. No bundle sheath.

g. The *fibro-vascular system.*

1. Most externally there may be included in the section the *hard bast*, or *primary phloëm*, seen to be composed of prosenchymatous, thick-walled cells with a few simple pits.

2. The *soft bast*, or secondary phloëm, consisting of several layers of cells, mostly oblong in form, with granular protoplasm and thin cell walls. Two kinds of elements are to be distinguished—(α) *cells* ; (β) *sieve tubes.* The latter have a different structure from those found in the primary bast of the Sunflower. They appear as more or less elongated cells, with oblique or transverse septa, and thin cell walls with granular protoplasmic contents. The sieve plates are not formed in the transverse septa, but are found on the radial longitudinal walls ; so that in the sections now under examination they are seen on surface view. They appear as oval or elongated angular areas on the cell walls, having a punctated appearance due to the perforations.

3. *Cambium*, consisting of narrow thin-walled oblong cells, containing protoplasm. Trace the radial rows of phloëm cells into continuity with these.

4. *Secondary xylem.* A thick band of tissue, composed of two elements, the cells of which are arranged differently according to the exact way in which the section has cut the xylem. These elements are the *vessels* and the *wood fibres.* The former consist of large tubes with thickened walls ; they are either of the pitted or reticulated kind. When seen in surface view the pits are found to be regularly arranged and bordered. As seen in section, the longitudinal walls present numerous depressions passing through the thickened part of the wall down to the common wall. Usually, the pits in adjacent vessels are placed opposite each other, so that the pitted walls present the appearance of rows of beads of cell wall, strung together, as it were, by the thin common cell wall. The thin transverse or oblique septa of the pitted vessels can be seen in some cases. The *wood fibres* are found in bands between the layers of vessels, and are prosenchymatous in form, with thickened walls and a few simple pits.

Near to the cambium band, are seen some young vessels which are narrower than the older ones, and have thinner walls; they have a few pits, and the transverse walls of the cells which compose these young vessels are distinctly seen.

If your section happen to have passed along a *secondary medullary ray*, or part of one, there are found numerous radial rows of oblong cells, with their long diameters placed longitudinally, and containing much granular and starchy contents. Their walls present pits, seen in section as rows of beads, which are found on the transverse as well as the longitudinal walls.

5. *Primary xylem*, lying internally to the secondary xylem, if your sections happen to have passed through it. It is found to consist of several *spiral vessels*, with a few parenchymatous cells scattered amongst them. They are larger near to the secondary xylem.

h. The central *medulla*, consisting of ordinary thin-walled parenchyma.

vi. Cut thin longitudinal *tangential* sections of the stem of **Sambucus.** Examine in the same way.

Observe :—

a. Varying appearances according to the tissue cut through.

b. In sections passing through the phloëm tangentially, the *radial* walls of the *sieve tubes* will be cut, and the sieve plates will appear as groups of perforations in those walls at slightly thickened spots. A few sieve plates will also be seen on surface view in the tangential walls.

c. In sections through the secondary xylem, the *secondary medullary* rays will be seen as longitudinal rows of cells of dark appearance, owing to granular protoplasm and starch grains. The cells are oblong in form, and have longitudinal and transverse pitted walls. They extend for a considerable distance longitudinally, but not throughout the whole height of the stem.

d. In other respects, compare with longitudinal radial sections.

vii. Carefully compare with Helianthus, noting the following points :—

a. *Cork tissue*, *cork cambium*, and *lenticels* in Elder, not in Sunflower.

b. Complete *broad bands* of secondary phloëm and xylem in Elder. These are only very poorly seen in Sunflower.

N.B.—The *fibro-vascular system* may be tabulated thus :—

Phloëm	**Primary**	=	**Bast fibres.**
	Secondary	=	**Bast cells.** **Bast vessels** (*sieve tubes*).
Cambium		=	*a complete ring of meristem.*
Xylem	**Secondary**	=	**Wood fibres.** **Vessels** (*pitted*). **Cells** (*second. med. rays*).
	Primary	=	**Vessels** (*spiral*). **Cells.**

v. The Root—Phaseolus.

i. Examine with the naked eye the young primary root of **Phaseolus**, obtained by germinating the seeds and taking the primary root or radicle when it has attained a few inches length.

Observe :—

a. The more or less cylindrical *primary* or *tap root*, bearing at its upper part—

b. Numerous *lateral roots*, which are longer and more developed in the upper part, and smaller towards the apex (*acropetal*). Note that they are arranged in regular longitudinal rows, four in number. This, as we shall presently see, corresponds in number to the xylem masses.

c. No secondary roots are found near to the apex of the primary root.

Cut thin transverse sections of a primary root of **Phaseolus,** which has been kept in alcohol for some days, selecting the part from which no secondary roots have been given off. Examine in glycerin with a low and afterwards a high power.

Observe :—

a. Most externally, the *epidermis*, giving off a few unicellular *root hairs*.

b. Just beneath it, a broad band of *cortical* fundamental tissue, consisting of thin-walled parenchyma with starch grains.

c. The *endodermis*, or *bundle sheath*, consisting of a single layer of cells considerably smaller than those of the cortical fundamental tissue.

d. The *fibro-vascular system*, or *cylinder*, occupying the central region of the root and made up of—

1. The *pericambium*, consisting of a single layer of cells, larger than those of the bundle sheath, and arranged in a somewhat columnar manner. The cells are thin walled, and the layer can be traced more or less completely around the cylinder. At *four* radiating points in its circumference it is seen to be not so easily traceable, and is here several layers of cells in thickness. It may even be seen to have grown out, and to form conical masses projecting into the cortical tissue.

2. Within the ring of pericambium, are seen *four* radiating isolated masses of **primary xylem,** which are placed opposite (*i.e.* in the same radii with) the thickened parts of the pericambium. Note that each xylem mass is wedge-shaped, with the apex applied to the inner aspect of the pericambium ring, and the base directed inwards. It has a yellowish appearance, and, with the high power, the walls of the cells composing it are seen to be thickened. The elements of the xylem are larger and have thinner walls towards the centre of the root (where the cells are developing into xylem). *The protoxylem of the root is external, whilst that of the stem is internal in position, and the primary xylem grows centripetally in the root, centrifugally in the stem.*

3. There may also be seen *four* isolated masses of **primary phloëm**, not nearly so well marked as the primary xylem. They alternate in position with the primary xylem masses, *i.e.* lie along radii alternating with those of the primary xylem masses.

4. Lying between the xylem and phloëm masses, are bands of parenchymatous tissue forming the *conjunctive* tissue of the fibro-vascular system.

e. Within the fibro-vascular cylinder, is a central mass of parenchymatous tissue, forming the *medulla*.

iii. Cut similar thin transverse sections of the older part of a primary root of **Phaseolus**, taking care that it is in the region of the lateral roots.

Observe :—

a. The same general arrangement of tissues as in ii.

b. Opposite to the xylem masses, the secondary roots are seen to spring as *endogenous* structures.

c. The lateral roots take origin from the pericambium, together with some of the cortical fundamental tissue.

d. The structure of the lateral roots can be seen in longitudinal section. A fibro-vascular bundle may be seen in the centre of the larger ones. In the younger lateral roots the arrangement of the cells at the apex may be made out (*vide infra*).

iv. Cut thin transverse sections of an old root of **Phaseolus** or other Dicotyledon.

Observe :—

a. The *cortical tissue* and *epidermis*. A certain amount of cork tissue has been produced in the cortical tissue.

b. Small masses of *primary phloëm*, arranged in a radiating manner, and not very easily distinguishable from—

c. The *secondary phloëm*, forming a narrow interrupted band lying at the peripheral part of the fibro-vascular system.

d. The *cambium*, not forming so complete a ring as in the stem, but otherwise having similar appearances and structure. It lies along radii different from the original primary xylem masses, and identical with the radii of the primary phloëm.

e. The *secondary xylem*, forming the secondary thickening of the fibro-vascular system, and consisting of a more or less continuous band; however, distinguishable into *four* wedge-shaped masses, *alternating* with the four masses of primary xylem.

f. Radiating bands of parenchymatous tissue, separating the four masses of secondary xylem, and lying in the same radii with the four primary xylem masses.

g. *Primary xylem* masses, having their original position.

h. The central *medulla.*

v. Cut thin longitudinal sections through the apex of the radicle of the seed of **Phaseolus.**

Observe :—

a. The structures detailed at page 43.

b. Particularly, note that there is no separate meristem for the calyptra, and that all the meristematic layers arise from a *common initial zone.*

vi. Cut thin longitudinal sections of the apex of the radicle in the seed of **Linum** or **Helianthus,** studying your sections with a low and high power. Having found a median section,

Observe :—

a. The *dermatogen.* Trace it upwards, and note that it splits into two layers. Tracing it still further, it is again seen to split into two layers, and so on repeatedly The outermost layers thus produced become the tissue of the *calyptra.*

The calyptra and dermatogen are thus seen to have a *common initial layer.*

b. The *periblem*, traced upwards, is seen to take origin from a second *initial layer*, of a single row of cells distinct from the dermatogen.

c. The *plerome*, traced upwards, is also found to arise from a special *initial* group of cells, distinct from the initial layer of the periblem. (Cf. *Phaseolus* and *Zea mais.*)

vi. Structure of Leaves—Helianthus, &c.

i. Examine a leaf of **Helianthus.**

Observe :—

a. Its attachment to the stem by a broad sort of cushion—the *pulvinus.*

b. The *petiole*, grooved on its upper surface.

c. An *axillary bud*, in the angle between the stem and the petiole.

d. The *lamina*, broad, flat, pointed, ovate in form. *Note*—the median prominent ridge or vein on its lower surface (*midrib*) ; the two similar lateral veins diverging from the median one near its base ; the branching of the three prominent veins, giving rise to a network of smaller veins in the general substance of the lamina (*reticulated venation*).

ii. Cut thin transverse sections of a **petiole.** Mount in glycerin, and examine with a low and high power.

Observe :—

a. The *outline* of the section, grooved or concave on its upper margin, convex on the lower.

b. The *epidermis.*

c. *Stomata*, in epidermal layer.

d. The *collenchyma*, a thick band just beneath the epidermis.

e. The general *parenchyma*, of thin-walled cells.

f. Isolated *fibro-vascular bundles*, arranged in a semicircle. No bundle sheath can be distinguished surrounding them. Of these bundles there are *three* large ones—one in the centre and two lateral (corresponding in the lamina to the three main *veins*). In addition, there are several smaller ones. Note the *structure* of the bundles.

1. *Xylem*, placed towards the upper or concave side of the petiole, and consisting of four or five rows of *vessels*, small at the apex of the xylem, larger towards the phloëm. Between the rows of vessels, are seen several rows of small thin-walled parenchymatous *cells*.

2. *Phloëm*, placed towards the convex side, made up almost entirely of soft bast, chiefly parenchymatous *cells*, with a few *sieve tubes* scattered amongst them.

3. *Cambium*, which is present in some of the bundles if the petiole is not old. If old, no cambium is seen ; so that the bundles are at first *open*, afterwards *closed*. (Cf. stem.)

g. The absence of *interfascicular* cambium. (Cf. stem.)

iii. Cut thin transverse sections of the **lamina.** This may be done by using material that has been hardened in spirit, and holding it between layers of elder-pith, or by folding the leaf and cutting several layers at the same time. Take care that your sections pass transversely through one of the three large veins. Examine with low and high powers.

Observe :—

a. The *midrib*, consisting of a mass of thin-walled parenchyma, causing a projection on the lower surface of the lamina. In it, note the large central fibro-vascular bundle, and one or two smaller lateral bundles. Note also, the same structure and position of the parts of the bundles as seen in the petiole.

b. The *thinner general tissue* of the *lamina*. In it, make out the following parts :—

1. Upper layer of *epidermis*, provided with a *cuticle* and giving attachment to numerous *hairs*. It possesses *stomata* with *guard cells*.

2. The *mesophyll*, made up of two kinds of chlorophyll-containing parenchymatous tissue ; *pallisade* parenchyma near the upper layer of epidermis, and more loosely arranged *spongy* parenchyma deeper in the leaf.

3. Small *fibro-vascular bundles*, variously cut in the section; some obliquely, some longitudinally, some transversely. They lie mostly about the middle of the sections, in the mesophyll. Some of them consist only of one or two spiral vessels.

4. The lower layer of *epidermis*, having *stomata* and *hairs*.

iv. Study the structure of the lamina in sections of the leaf of **Laurel.**

Observe :—

a. The same general arrangement of tissues as seen in Helianthus.

b. The *thicker* cuticle.

c. *Absence of stomata* in the upper layer of epidermis; large numbers in the lower layer. (*See* structure of stomata at page 22.)

v. Strip off and mount in glycerin the epidermis from the upper and lower surfaces of the leaf of **Laurel.**

Observe :—

Absence of stomata in former, their presence in the latter. (*See* page 22.)

N.B.—The upper and lower surfaces of the leaves and the tissue near these surfaces present different arrangements and structures. In the following leaf the two surfaces are alike.

vi. Cut thin transverse sections of the leaf of **Dianthus caryophyllus.** Examine in glycerin with a high power.

Observe :—

a. The upper *epidermis*, a single layer of cells, free from chlorophyll grains. Note the thick stratified cuticle.

b. The very numerous and distinct *stomata*, each having two small depressed guard cells, with thickened stratified walls.

c. The *mesophyll*, made up of—

1. Upper layer of parenchyma, composed of cells arranged in a more or less *pallisade* fashion, and containing much *chlorophyll.* Note the large intercellular spaces into which the stomata open.

2. A *middle layer* of mesophyll, consisting of large rounded, loosely-arranged, *spongy* parenchyma, containing much less chlorophyll than 1.

3. A lower layer of parenchyma exactly similar to 1. 1 and 3 can be shown to be continuous by tracing them towards the margin of the leaf.

d. *Fibro-vascular bundles*, lying in the central layer of mesophyll, and each consisting of a layer of *hard bast* towards the lower surface of the leaf, then several layers of cells forming *soft bast*, and consisting chiefly of parenchyma, then a layer or two of *xylem fibres*, and nearest to the upper surface of the leaf a mass of spiral and annular *vessels.*

e. The lower *epidermis*, precisely similar to the upper.

vii. General Morphology of Leaves.

A. Kinds of Leaves.

i. Examine with the naked eye, and dissect a *bud* from the termination of a branch of **Æsculus** or **Acer.** It is found in spring.

Observe :—

a. The main axis of the bud, bearing young foliage leaves, the whole being covered externally by—

b. Brown, thin, imbricated *scales.* These are **cataphyllary** leaves, and fall off as the bud expands. They are the lowest and first formed leaves of each annual shoot.

ii. Examine the ordinary **foliage** leaves of **Helianthus** or other type. They have buds or branches in their axils.

iii. Examine the floral region of **Helianthus.**

Observe :—

a. The ring of green leaves which surrounds the expanded flower-head and forms what is called an *involucre.*

b. On cutting a longitudinal section through the flower-head, there are seen numerous small scale-like bodies in whose axils the flowers are situated.

Both of these are *bracts*, or **hypsophyllary** leaves. Such leaves are usually found in that part of the plant which bears the flowers, and the pedicels of the flowers arise from the main axis in their axils.

iv. The leaves which compose the various rings of members in the *flower* are a fourth kind of leaves, which may be distinguished under the name of **floral** leaves.

B. Forms of Leaves.

Examine with the naked eye the leaves from **various types,** making out the characters mentioned in each case.

i. In some cases the leaf consists of petiole and lamina only—**Helianthus.**

ii. In a few cases there is superadded a *sheath*, situated at the base of the petiole, and embracing the stem for some distance—various **Umbelliferæ.**

iii. There may be added, also, a *ligule*—a small outgrowth seen in **Grasses,** and occurring at the junction of the sheath and lamina.

iv. Sometimes the petiole is absent—*sessile*. **Sedum acre.**

v. Occasionally the leaf sheath becomes modified into two "leaf-like" structures at the base of the true leaf—*stipules*. **Vicia faba.**

vi. The *venation*, or arrangement of "veins" varies.

a. *Pinnate*, when secondary "veins" are given off regularly from both sides of the midrib, like the barbs of a feather—**Fagus** (Beech).

b. *Palmate*, when the "vein" entering the leaf blade divides at once into several equal and diverging "veins"—**Hedera helix.**

c. *Reticulated*, when the "veins" frequently anastomose—**Helianthus.**

d. *Parallel.* Several "veins" run nearly straight along the blade—**Zea mais.**

vii. The *form of the lamina* presents endless variations, of which the following are some of the most important :—

- *a.* **Simple,** when the lamina is either undivided or imperfectly segmented.
    1. *Cordate*—some of those of **Helianthus.**
    2. *Lanceolate*—**Cheiranthus.**
    3. *Ovate*—leaflets of **Rosa canina.**
    4. *Sagittate.*
    5. *Acicular*—**Pinus.**
    6. *Linear*—**Grasses.**
    7. *Obovate.*
    8. *Orbicular.*
    9. *Obcordate*—leaflets of **Oxalis.**
    10. *Peltate*—**Nasturtium.**
- *b.* **Compound,** when the lamina is divided completely into secondary laminæ connected by secondary petioles.
    1. *Pinnate*—**Pisum sativum.**
    2. *Ternate*—**Trifolium.**
    3. *Palmate*—**Æsculus.**

viii. Sometimes the leaf, or a part of the leaf, takes the form of **tendrils,** *e.g.*, **Pisum,** where the upper leaflets of the pinnate compound leaf take this form.

ix. The *texture* of the leaf is various.

- *a.* *Herbaceous*—**Helianthus.**
- *b.* *Coriaceous*—**Prunus lauro-cerasus.**
- *c.* *Fleshy*—**Sedum acre.**

x. The *form* of the leaf *in the bud* (**vernation**), presents the following varieties, which can be made out by cutting transverse sections of the bud :—

- *a.* *Conduplicate*, when the two halves are folded inwards from the midrib—**Vicia faba.**
- *b.* *Plicate*, when the leaf is thrown into numerous longitudinal folds—**Fagus.**

c. *Crumpled*, when the leaf is folded in any direction—*petals* of **Papaver.**

d. *Involute*, when the margins of the leaf are curved inwards towards the midrib—**Pyrus malus** (Apple).

e. *Revolute*, when the margins of the leaf are curved outwards towards the midrib.

f. *Convolute*, when the whole leaf is rolled up from the margin so as to form a coil—**Prunus avium** (Cherry).

g. *Circinate*—**Ferns.**

C. Arrangement of Leaves.

Examine and make out the various arrangements of leaves in the following types :—

i. Arrangement of leaves *on the stem* (**phyllotaxis**).

a. *Whorled*, when several leaves spring from the same node. Best seen in typical *cyclic* flowers (*vide infra*). Spurious whorls may be produced in two ways—when several internodes are either very short or suppressed ; and when the stipules are large and conspicuous, and in every way like the true leaves, except in not having branches in their axils, *e.g.*, various species of **Galium.**

b. *Opposite*, when two leaves spring from one node on opposite sides of the stem. Various **Labiates.**

c. *Decussate*, when two opposite leaves at one node alternate with those at the node above and below. **Lamium album.**

d. *Scattered*, when only one leaf springs from each node. When this is the case, the lateral distance of the insertion of one leaf from the next, measured on the circumference of the stem, is called the *divergence*. This divergence is usually constant in any given type. A line can be drawn through the points of insertion of the leaves in succession, and will be found to pass round and round the stem in a spiral manner. Such a line is called the *genetic spiral*. If the divergence be constant, it is clear that if we trace the spiral for some considerable distance up the stem, we shall come to leaves which lie in the same vertical line on the surface of the stem as leaves lower down. A certain number of such vertical rows of leaves, varying according to the divergence, can usually be distinguished. These are called *orthostichies.*

If, in tracing a genetic spiral, we find that every fourth leaf is in the same orthostichy as the leaf we started from, then, obviously, in each spiral turn three leaves are included, and the divergence is one-third of the circumference of the stem. The phyllotaxis is then said to be one-third. Similarly, if we find it necessary to pass *twice* round the stem before coming to a leaf in the same orthostichy with that from which we started, and if five leaves are included in these two turns of the spiral, then the divergence is two-fifths. This divergence is by far the most common. Other divergences, *e.g.*, one-half, three-eighths, five-thirteenths, &c., occur.

Examples of two-fifths phyllotaxis = **Pyrus malus, Quercus robur, Rosa,** &c.

ii. Arrangement of leaves *in the bud*—**prefoliation,** or, in the case of the floral leaves, **æstivation.**

a. *Imbricate* prefoliation. This is applied to the case in which the leaves overlap each other at their edges.—**Scale leaves** in most **buds.**

b. *Valvate* prefoliation. When the leaves in the bud do not overlap each other, but their edges, which may be revolute, involute, &c., only meet—corolla of **Syringa** (Lilac), **Vitis,** &c.

viii. Varieties of Inflorescences.

The inflorescence is the portion of the plant which consists of that part of the primary or secondary axis which bears flowers in the axils of certain special leaves or bracts. The varieties of inflorescences are distinguished, in the main, according to the mode of branching of the stem in the floral region.

Dichotomous branching in connection with inflorescences is very rare, all the chief varieties being founded on the *monopodial* system of branching.

A. **Racemose** inflorescences.

i. Examine the inflorescence of **Plantago major.**

Observe :—

a. The main axis of the inflorescence or *rachis.*

b. The *bracts,* in whose axils are found—

c. The *flowers :* each is *sessile.*

Such an inflorescence is called a **spike.**

ii. A variety of spike is afforded by the inflorescence of **Arum** (a Monocotyledon), which differs from the spike in having a fleshy axis and in possessing a large sheathing bract enclosing the rachis and flowers. It is known as the **spadix.**

iii. Examine the inflorescence of **Cheiranthus cheiri.**

Observe :—

a. The *rachis,* bearing *bracts.*

b. The *flowers,* in the axils of the bracts. They are not sessile, but have moderately long pedicels.

This inflorescence is known as the **raceme,** and is very common.

iv. Examine the inflorescence of **Conium maculatum.**

Observe :—

a. The *rachis* and *bracts.*

b. The large number of secondary axes, springing close together from a very abbreviated part of the main rachis.

c. Each of the secondary axes, again, bears at its summit a large number of flowers with long pedicels, springing close together from the abbreviated part of the secondary axes.

This kind of inflorescence is the **umbel,** that one described being a *compound umbel.*

v. Examine the inflorescence of **Helianthus.**

Observe :—

a. The very much shortened and expanded summit of the main axis, forming a disk.

b. The *involucre* of bracts, surrounding the disk at its margins.

c. The densely crowded *flowers*, at the summit of the expanded disk. Each flower consists of a very short axis bearing the floral leaves at its summit.

d. Small *bracteoles*, lying between the flowers, and in whose axils the flowers have been developed.

Such an inflorescence, having a very abbreviated axis and densely crowded flowers, is known as the **capitulum.**

vi. A variety of spike found amongst the Grasses (Monocotyledons) consists of a main rachis bearing secondary axes, each of which is a simple spike.

This inflorescence is a **compound spike.**

vii. Examine the inflorescence of **Ranunculus acris.**

Observe :—

a. The *rachis.*

b. Branches of the rachis, which, instead of terminating in a single flower, again branch and bear flowers on the branches.

This is an example of a **compound raceme** or **panicle.**

viii. Examine the inflorescence of **Chrysanthemum parthenium.**

Observe :—

That it consists of a number of capitula, like those of Helianthus, arranged in a raceme. This is an instance of a heterogeneously compound inflorescence, and may be called the **capitulate raceme.**

B. **Cymose** inflorescences. These are produced when the main axis terminates in a flower and bears branches just below its apex, each of which ends in a flower, but grows more vigorously than the main axis, and again repeats this mode of branching.

ix. Examine the inflorescence of **Hypericum.**

Observe :—

a. The main axis or rachis, ending in a flower, beneath which are seen—

b. Branches, each again ending in a single flower, and giving off other branches which repeat this arrangement.

This kind of inflorescence is called the **cyme.**

x. A variety of cyme, in which the lateral branches of the successive ramifications occur always on the same side of the inflorescence, or are more strongly developed, always on one side, occurs sometimes, though not commonly. It is called the **helicoid cyme.**

xi. A third variety of cyme, in which successive lateral branches occur on *alternate* sides of the inflorescence, is also found sometimes, *e.g.*, **Atropa belladonna.** It is called the **scorpioid cyme.**

N.B.—Some inflorescences, which at first sight appear to be cymes of one of the last two varieties, are not really so, but are *unilateral racemes.*

ix. The General Structure of the Flower.

i. Examine the flowers of **Ranunculus acris,** by removing *seriatim* the various parts of the flower, and by making longitudinal sections, using, when needed, the simple microscope or a pocket lens.

Observe :—

a. The *calyx*, or outer layer of leaves, made up of five *sepals.* Note the form and colour of the sepals. Each is separate from its neighbours (*eleutherosepalous*) ; the calyx is also *inferior.*

b. The *corolla*, the most conspicuous part of the flower, consisting of *five* (sometimes more) petals, alternating with the sepals. They are *eleutheropetalous* and *hypogynous.*

c. The *andrœcium*, consisting of an indefinite number of *stamens*, each separate from the rest (*polyandrous*), and inserted beneath the next part of the flower (*hypogynous*). Note that each stamen is made up of a *filament* or stalk, bearing an *anther* at its summit.

d. The *gynœcium*, consisting of a large number of separate and distinct *carpels* (*apocarpous*). Each carpel consists of a single carpellary leaf, folded over to enclose a cavity (the *ovary*). There are thus as many ovaries as there are carpels. Surmounting each carpel is a *stigma*, upon which the pollen, produced in the stamens, falls. The whole gynœcium is *superior*. In each carpel, note the single *ovule*.

e. The *disk*, *torus*, or *thalamus*, consisting of the convex termination of the floral axis, and upon which the series of leaves described above are inserted. Carefully note the relative positions of the various kinds of floral leaves at their attachment to the torus.

ii. Examine in the same way the flower of **Cheiranthus cheiri** (Wallflower).

Observe :—

a. The *calyx*, made up of two rings of *sepals*, having *two* sepals in each ring. Note that the two sepals in the inner ring alternate with those of the outer ring. Each sepal is separate from its neighbours (*eleutherosepalous*) ; each is also *inferior*.

b. The *corolla*, made up of *one* ring of *four* petals. They alternate with the four sepals, are *eleutheropetalous*, and *hypogynous*.

c. The *andrœcium*, consisting of *six* stamens. Two of these form an outer ring or whorl, and are *opposite* the two inner sepals. The other four form a second whorl, and are *opposite* the four petals. The latter four are longer than the other two (*tetradynamous*). Each stamen is *hypogynous* and *free* (*hexandrous*).

d. The *gynœcium*, consisting of *two* carpels united together (*syncarpous*). In position they are opposite to the two outer stamens. The gynœcium is free from all other parts of the flower (*superior*). Surmounting the gynœcium, note the short *style* and the bilobed *stigma* at its summit. In the gynœcium note—

1. Two *ovaries*, or chambers, separated by a membrane, not formed of the incurved margins of the carpels, but by—
2. A false dissepiment, or *replum*.
3. The two rows of ovules in each ovary, attached to the incurved margins of the carpels (*parietal marginal placentation*).

These two types serve to illustrate that division of the Dicotyledons known as *Thalamifloræ*, and have these characters in common :—

1. *Eleutheropetalous* corolla.
2. *Hypogynous* petals and stamens.
3. *Superior* gynœcium.

iii. Examine in the same way the flower of **Pisum sativum** (common garden Pea).

Observe :—

a. *Calyx*, consisting of *five* sepals in one ring, confluent at their base (*gamosepalous*), so as to form a green cup-like structure. At their base they are attached to the margins of a concave receptacle, but are still *inferior*.

b. *Corolla*, having an irregular form, butterfly-like (*papilionaceous*), made up of *five* petals, an upper one very large and expanding over the others (*vexillum*). Laterally, two small ones having a stalk (*alæ*). Inferiorly, two oval petals loosely united in the middle line (*carina*). The corolla is inserted on the margins of the concave receptacle (*perigynous*) and is (except the inferior two petals) *eleutheropetalous*.

c. The *andrœcium*, consisting of a ring of *ten* stamens. Nine of these are united together below by their filaments, whilst their anthers are free. The tenth stamen is separate from the rest. Hence the stamens are in two bundles (*diadelphous*). They are inserted on the margins of the concave receptacle (*perigynous*).

d. The *gynœcium*, consisting of a single carpellary leaf, folded over so as to enclose the *ovary*. It is *apocarpous* and *superior*. In the carpel, note the *ovules* attached along the *ventral* suture (*parietal*).

e. The small, shallow *concave receptacle*, from the centre of which the gynœcium springs.

iv. Examine in the same way the flower of **Rosa canina** (Dog-Rose).

Observe :—

a. *Calyx*—five sepals, *gamosepalous*, *inferior*, attached to the margins of the very distinct hollow receptacle.

b. *Corolla*, very conspicuous, consisting of five eleutheropetalous petals—regular—*perigynous*.

c. The *andrœcium*, consisting of several whorls of stamens, altogether a very large number. They are all separate from each other (*polyandrous*), and are inserted on the margins of the concave receptacle (*perigynous*).

d. The *gynœcium*, consisting of several carpels, enclosed within the hollow receptacle. They are *apocarpous* and *superior*. Each has a very distinct long *style*, terminated by a knob-like *stigma*. In each is a single ovule.

e. The *hollow receptacle*, broad below, narrow at the summit. Later on, this becomes thick and succulent, and encloses the fruits.

These two types are selected to illustrate the characters of that division of Dicotyledons called the *Calycifloræ*, and have the following common characteristic features—

1. *Eleutheropetalous* corolla.
2. *Perigynous* corolla and andrœcium.
3. A *concave* receptacle.

v. Examine in the same way the flower of **Primula vulgaris** (Primrose).

Observe :—

a. *Calyx*, green, *gamosepalous* and *inferior*.

b. The *corolla*, conspicuous, consisting of a tube, spreading out at its summit into a disk, divided into five parts (*petals*). It is therefore *gamopetalous*. The tube is *hypogynous*.

c. The *andrœcium*, consisting of five stamens, attached within the tube of the corolla to the petals (*epipetalous*). Each stamen is *opposite* a petal. In some flowers the stamens are found about halfway up the tube of the corolla ; in others, near the summit of the tube. Each stamen is distinct from the others (*pentandrous*).

d. The *gynœcium*, consisting of a globular body at the bottom of the tube of the corolla (the *ovary*), surmounted by a long rod-like *style*, at whose summit is a rounded *stigma*. The gynœcium is really made up of *five* carpels; but on cutting a transverse section of the ovary, only *one* cavity is seen. In this cavity is found a central mass of tissue (the *axis* of the flower) forming a free central *axial placenta*, on which numerous *lateral* ovules are seen. The gynœcium is *syncarpous* and *superior*.

vi. Examine in the same way a *flower-head* of **Helianthus.**

Observe:—

a. The *capitate* inflorescence (*see* page 131).

b. The *florets of the ray*, consisting of the expanded, *ligulate*, *conspicuous* florets found in the peripheral parts of the flower-head.

c. The *florets of the disk*, consisting of the central smaller *tubular* florets.

d. The *involucre* of bracts.

vii. Examine carefully one of the **florets of the disk.**

Observe:—

a. The *short floral axis*, attached to the expanded summit of the stem in the axil of a *bract*, and bearing the floral leaves.

b. The *calyx*, consisting of a ring of very minute *sepals* at the summit of the "inferior ovary." It is therefore *superior*.

c. The *corolla*, conspicuous, consisting of a tube, attached below to the summit of the ovary (*epigynous*), and having five teeth at its margin. This shows that it is made up of five united *petals* (*gamopetalous*).

d. The *andrœcium* (seen on splitting open the tube of the corolla). It consists of five *stamens*, attached within the tube of the corolla to the united petals (*epipetalous*). Note in each stamen, the short filament and the large elongated anther. The anthers of the five stamens are loosely united together (*syngenesious*) *e.* The *gynœcium*, imbedded in the upper part of the axis of the flower, and indistinguishable from it (*inferior*). The cavity seen in this situation is the *unilocular* ovary, and is by inference regarded as consisting of two carpels, on account of the two stigmas. It contains a single ovule. Passing upwards from the summit of the ovary is a long filiform *style*, enclosed by the tube of the corolla and by a tube formed of the syngenesious anthers. It is divided into two at its summit, the two parts being the two *stigmas*. The gynœcium is *syncarpous*.

N.B.—The Primula and Helianthus are types of that division of Dicotyledons known as the *Corolliflorœ*, which have the common character of possessing a *gamopetalous* corolla. (Cf. Thalamifloræ and Calycifloræ.)

viii. For each of the above flowers fill up, as far as you can, a table on the plan of the following:—

PRIMULA VULGARIS.

	No.	*Cohesion.*	*Adhesion.*	*Peculiarities.*
Calyx *sepals*	} 5	gamosepalous	inferior	regular.
Corolla *petals*	} 5	gamopetalous	hypogynous	regular.
Andrœcium *stamens*	} 5	pentandrous	epipetalous	{ opposite to the petals.
Gynœcium *carpels*	} 5	syncarpous	superior	unilocular.
Ovules—several.				
Placentation—axial, lateral.				

x. The Flower (continued).—Floral Diagrams and Formulæ.

i. Examine with the naked eye the general character of the flower of **Vicia faba.**

Observe :—

That you can divide it by a median incision, passing through the vexillum and the carina, and bisecting the ring of stamens and the single carpel, into *two lateral symmetrical halves.* You are unable to divide the flower *symmetrically* except by this incision. Such a flower is called **zygomorphic,** or **monosymmetrical.**

ii. Observe the same fact, by examining the flower of **Lamium album** (Deadnettle). It also is zygomorphic.

iii. Examine the flower of **Geranium,** by dissecting it and by cutting it longitudinally.

Observe :—

a. One ring of five *calycine leaves* (sepals).

b. One ring of five alternating *corolline leaves* (petals).

c. Two alternating rings of *staminal leaves*, the outer one alternating with the ring of corolline leaves.

d. One ring of five *carpellary leaves*, united into a median column (*syncarpous*). They alternate with the inner ring of staminal leaves.

e. You can divide the flower into *symmetrical halves* by sections in *more than one* situation. You can do so by any one of *five* incisions. Such a flower is called **actinomorphic,** or **polysymmetrical.**

iv. Examine the flower of **Cheiranthus cheiri,** and observe its *actinomorphic* character.

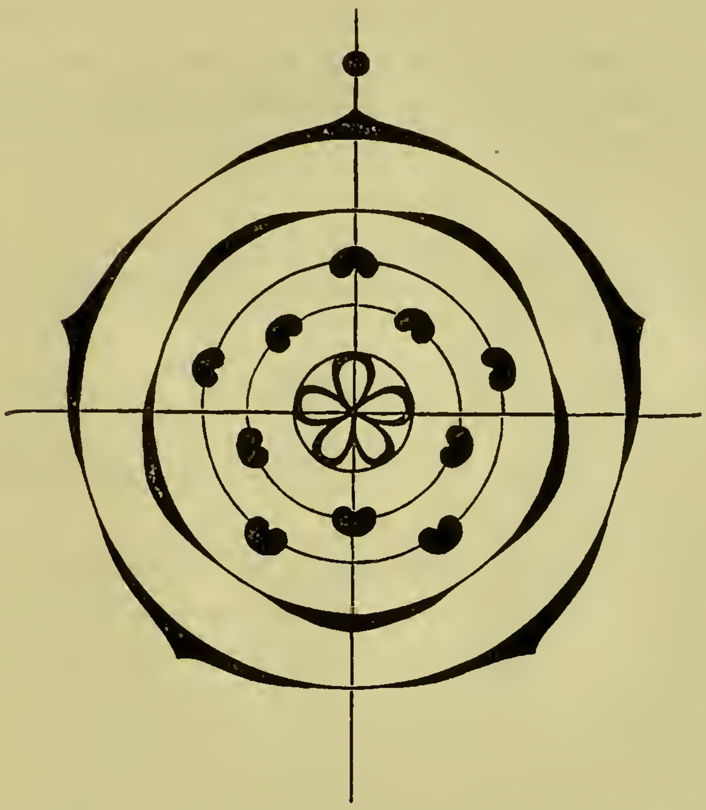
v. Remove carefully, in order, the members of the various rings of leaves in the flower of **Geranium,** fixing them by means of gum or by pins on a large sheet of paper, in a series of *concentric* rings, corresponding to the natural rings in the flower.

Observe :—

a. As you remove the parts of each ring, that successive rings form *whorls*, and that the members of each whorl are distinct from adjacent ones.

b. The members of successive whorls alternate with those of the whorls immediately internal and external.

c. The arrangement of the parts of the flower may be represented by the following diagram :—



In this diagram the outer ring represents the calyx, the next the corolla, the next two the stamens, and the innermost the carpels.

d. The position of the main axis of the inflorescence, with respect to the parts of the flower. It is represented in the above diagram by the dot outside the outer ring at the upper part. A line drawn through this dot and the centre of the diagram represents the **median plane** of the flower. A line passing through the centre of the diagram at right angles to this line represents the **lateral plane.** Other lines bisecting the right angles at the centre of the diagram correspond to the **diagonal planes** of the flower.

e. The parts of the flower lying nearest the *main axis* are said to be *posterior* in position. Those farthest from the main axis are said to be *anterior* in position. Note that in Geranium there is a single posterior sepal and a single anterior petal.

N.B.—Such a diagram as the above is called a **floral diagram,** and is a very convenient way of expressing the arrangement, &c., of the parts of a flower. Sometimes some of the parts of a flower are suppressed, and the position of these can be represented by a small dot where they would otherwise be found. A diagram of this kind is called a *theoretical diagram.*

vi. Remove and lay out in the same way the parts of the flower in **several types** of flowers, in each case constructing a diagram like the above, taking care to mark the position of the axis and of the planes of the flower. Work with *Cheiranthus*, *Rosa*, *Pisum*, *Primula*, *Linum*, and others.

N.B.—All flowers which are constructed on this plan, *i.e.*, have successive *whorls* of leaves, are called **cyclic** flowers; and when the number of leaves in each whorl is the same, the flower is said to be **eucyclic.**

vii. Examine carefully the flower of **Ranunculus.**

Observe :—

That the successive rings of leaves (sepals, petals, &c.) are *not* arranged in whorls, but form a continuous *spiral* passing unbroken from sepals to petals, and from them to stamens and carpels.

Such a flower is said to be **acyclic,** and in some such cases, *e.g.*, *Nymphæa*, there is no abrupt line to be drawn between sepals, petals, stamens, and carpels, which are connected together by a continuous series of intermediate forms.

viii. It is sometimes convenient to express the arrangement and number of the parts of a flower by what is called a **floral formula.**

Satisfy yourself that the following represents shortly the characters of the flower of *Geranium* :—

$$\mathrm{K}\ 5,\ \mathrm{C}\ 5,\ \mathrm{A}\ 5+5,\ \mathrm{G}\frac{5}{\ }.$$

In this *formula* K stands for calyx, C for corolla, A for andrœcium, G for gynœcium. The figures represent the number of leaves in each whorl, and the figure placed *above* the line after G shows that the gynœcium is *superior.*

Write a floral formula of this kind for every type of flower you examine.

xi. The Andrœcium.

i. Examine a stamen from the mature flower of **Ranunculus bulbosus** or **acris**.

Observe :—

a. The *filament.*

b. The *anther*, a bilobed structure on the summit of the filament.

c. The *pollen*, dust-like material, escaping from a longitudinal slit in the anther.

ii. Cut thin transverse sections of a flower bud of **Ranunculus**, which has been hardened in alcohol.

Observe :—

The transverse sections of the *anthers*. In each note—

1. The bilobed outline of the anther.
2. The large cavities, one in each lobe—*pollen sacs.*
3. Remains of a *septum* in each cavity, showing that each was originally made up of two pollen sacs.
4. The *connective* or central part of the anther, between the two lobes. It contains a fibro-vascular bundle.
5. The *wall* of the *pollen sac*, made up of three layers of cells—an outer *epidermis*, a second layer of thick-walled cells, and an inner one of delicate cells.
6. The *pollen grains*—some in the pollen sacs, others in the surrounding fluid.

N.B.—The pollen sacs represent the *microsporangia*, and the pollen grains the *microspores* of the higher Vascular Cryptogamia.

iii. Examine the ripe pollen of **Ranunculus**, in glycerin, with a high power.

Observe :—

1. Outer *cell wall.*
2. *Protoplasmic contents.*
3. *Globular form.*
4. *Absence* of a vegetative cell. (Cf. *Pinus.*)

iv. Examine the ripe pollen of **Helianthus.**

Observe :—

a. The *cell wall*, with external spine-like thickenings upon it.

b. The *protoplasm.*

c. *Absence* of a vegetative cell.

v. Cut very thin transverse sections of a flowering head of **Helianthus**, in various stages, so as to obtain sections showing the development of pollen.

Observe :—

a. In very young anthers, a central mass of large cells occupying the lobes of the anther, *two* masses lying in each lobe. These are the *mother-cells* of the pollen grains. They are surrounded by the wall of the anther, made up of three layers of cells.

b. In older anthers, the division of the mother-cells, each into *four* daughter-cells. As these daughter-cells are being produced they appear to become surrounded and separated from each other by projecting ingrowths of cellulose from the mother cell wall. The wall of each daughter-cell soon appears to become distinct from that of the mother-cell, and is really produced by the protoplasm of the daughter-cells during the process of their development. Each daughter-cell becomes a pollen grain. This stage is much more easily obtained than the first.

c. In still older anthers, the gradual separation of the four daughter-cells, the absorption of the mother-cell wall, and liberation of the pollen grains.

vi. Examine carefully the ripe **stamens** of the following types, directing your attention to the way in which the anther lobes split so as to allow the pollen to escape. A pocket lens or simple microscope will be required.

Observe :—

a. In **Helianthus,** the pollen sacs open or dehisce by the formation of longitudinal slits on the inner surface, *i.e.*, that turned towards the gynœcium. This is **introrse** dehiscence, and is the most common.

b. In **Cheiranthus,** the same *introrse* dehiscence is found.

c. In **Ranunculus,** the pollen sacs split longitudinally by an aperture on the external surface of the anthers (**extrorse** dehiscence).

d. In **Erica,** the pollen sacs open by small pores at their summits (**porous** dehiscence). In Erica, note also the filiform appendage projecting outwards from the base of each pollen sac.

vii. Examine the **andrœcium** of **Hypericum.**

Observe :—

Five bundles of stamens. Each bundle consists of many filaments, each terminated by an anther. This condition is really brought about by the *branching* of five originally *simple* stamens, not by the partial union of many originally separate stamens. This is often called **polyadelphous.** (Cf. *diadelphous* andrœcium of Pisum.)

Another example of branched stamens is afforded by **Ricinus.**

viii. Examine, by means of a simple microscope, the **andrœcium** of **Salvia officinalis.**

Observe :—

a. The *filament*, surmounted by—

b. The *transversely elongated connective*, loosely attached to the summit of the filament, where it forms a kind of hinge.

c. At one extremity of the connective there is found a perfect *pollen sac* (*i.e.*, one half of the anther), containing pollen ; and at the other or lower extremity of the connective is found an imperfect pollen sac, often containing no pollen at all.

ix. When the anther is inserted simply at the summit of the filament, *e.g.*, **Helianthus, Ranunculus,** and many others, the anther is said to be **innate.**

N.B.—Another kind of anther—the **versatile** or freely swinging anther—is found most commonly amongst Monocotyledons.

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xii. The Gynœcium.

i. Examine the gynœcium of **Phaseolus** or **Vicia faba,** by dissecting the flower, and by longitudinal and transverse sections viewed with a low power.

Observe :—

a. Gynœcium is *superior.*

b. It is *monocarpellary* and has a single *ovary.*

c. Ovules are attached to the incurved margins of the carpel (*parietal marginal* placentation).

d. Ovules numerous.

ii. Examine in the same way the gynœcium of **Ranunculus.**

Observe :—

a. Gynœcium is *superior.*

b. It consists of *several* apocarpous carpels.

c. *Each carpel* forms an ovary.

d. Ovules are attached to the carpels.

e. *One ovule* in each ovary.

iii. Examine, in the same way, the gynœcium of **Viola.**

Observe :—

a. Gynœcium is *superior.*

b. It consists of *three* carpels, united at their margins (*trimerous, syncarpous*).

c. There is *one* ovary (*unilocular*).

d. Ovules are attached to the margins of the carpels (*parietal marginal*).

e. Several ovules in each carpel.

f. Ovules *anatropous.*

iv. Examine in the same way the gynœcium of **Solanum dulcamara.**

Observe :—

a. Gynœcium is *superior.*

b. It consists of *two* syncarpous carpels, whose margins are incurved so as to reach the centre, thus dividing the gynœcium into—

c. *Two ovaries* (*dimerous, bilocular*).

d. Several *anatropous* ovules attached to the incurved margins of the carpels (so called *axile*, but really *parietal* marginal).

v. Examine in the same way the gynœcium of **Polygonum.**

Observe :—

a. *Superior* gynœcium.

b. One *ovary* chamber (really composed of three syncarpous carpels). It is therefore *trimerous* and *unilocular.*

c. *One ovule*, erect, *orthotropous.*

d. It is attached to the termination of the floral axis (*axial terminal* placentation).

vi. Examine in the same way the gynœcium of **Primula.**

Observe :—

a. Superior gynœcium.

b. One-chambered ovary (really composed of *five* carpels, *i.e., pentamerous, unilocular*).

c. Ovules attached to the sides of a central column, a prolongation of the floral axis (*axial lateral ; free central* placentation).

d. Several *anatropous* ovules.

vii. Examine in the same way the gynœcium of **Helianthus.**

Observe :—

a. The gynœcium is *inferior.*

b. It consists of *two* carpels (shown by the *bilobed* stigma). They are *syncarpous.*

c. There is *one* chamber in the ovary (*unilocular, dimerous*).

d. *One* ovule in the ovary. It is apparently terminal—really *lateral.* It is anatropous. Placentation, *axial lateral.*

viii. Examine in the same way the gynœcium of **Conium maculatum.**

Observe :—

a. *Inferior* gynœcium.

b. *Two* syncarpous carpels.

c. *Two* ovary chambers.

d. Single pendulous ovule in each chamber, *anatropous ; parietal* placentation.

TABLE SHOWING THE VARIETIES OF GYNŒCIA.

(i.) Gynœcium superior.
  A. Placentation parietal.
    a. Ovary monocarpellary.
      1. One ovary in the flower (*Phaseolus*).
      2. Two or more ovaries (*Ranunculus*).
    b. Ovary polycarpellary.
      1. Ovary unilocular (*Viola*).
      2. Ovary multilocular (*Solanum*).
  B. Placentation axial.
    a. Ovule solitary, terminal (*Polygonum*).
    b. Ovules many, lateral (*Primula*).

(ii.) Gynœcium inferior.

- A. Placentation parietal.
  - *a.* Ovary multilocular (*Conium*).
  - *b.* Ovary unilocular (rare).
- B. Placentation axial.
  - *a.* Ovule or ovules lateral (*Helianthus*).
  - *b.* Ovule terminal (rare).

ix. Cut thin longitudinal sections of a young flower-head of **Helianthus.** Mount in glycerin, and examine with low and high powers, directing your attention to the **ovules.**

Observe :—

a. Solitary ovule.

b. Its structure—a *funicle* or stalk, adherent to the inverted body of the ovule in the greater part of its extent (*anatropous*) ; the *body* of the ovule made up of a central mass of parenchymatous cells, the *nucellus*, surrounded by two *integuments*, each several layers of cells in thickness,—these cover the nucellus at all points, except a narrow canal at the summit (*micropyle*) ; in the nucellus near its upper part is a single large cell, the *embryo-sac.* In a thin and fortunate section there may be seen in the embryo-sac—

1. One or two large *vacuoles.*
2. Granular *protoplasm.*
3. A large *nucleus.*
4. Three nucleated cells at the anterior end of the sac, viz., the *oosphere*, covered by the two *synergidæ.*
5. At the posterior end of the sac, there are also found three cells, the *antipodal cells.*

The contents of the embryo-sac may also be studied in *Viola tricolor* or *Caltha palustris* ; or in *Lilium* amongst Monocotyledons.

N.B.—The ovule represents the *macrosporangia*, and the embryo-sac the *macrospores* of the Vascular Cryptogamia. The *female prothallus* of the Vascular Cryptogams is represented by the antipodal cells, the protoplasm of the embryo-sac, and the endosperm formed *subsequent* to fertilization.

x. Take a flower of **Capsella bursa pastoris**, in which the petals have just fallen, and pick out the ovules, mounting in glycerin. If they are not sufficiently transparent, treat with dilute potash and mount.

Observe :—

a. The *funicle.*

b. The *integuments* (two).

c. The *nucellus*, with a very large *embryo-sac*, occupying its greater part.

d. The *form* of the ovule. The body of the ovule is *bent upon itself* (not merely inverted), *i.e.*, is *campylotropous.* (Cf. anatropous.)

xi. Dissect out, and examine in the same way, the ovules of **Solanum dulcamara.**

Observe :—

The *campylotropous* form of the ovule.

xii. Dissect the gynœcium of **Polygonum**, so as to make out the characters of the ovule.

Observe :—

The *orthotropous* form of the ovule, *i.e.*, the funicle and body in the same vertical line, so that the micropyle is opposite the funicle. (Cf. anatropous and campylotropous.)

xiii. Make out the **placentation** of the ovules in the gynœcia of the following types. This can be done by cutting transverse and longitudinal sections.

Phaseolus—parietal marginal.

Butomus (a Monocotyledon)—parietal superficial.

Helianthus—axial lateral.

Primula—axial lateral.

Polygonum—axial terminal.

xiii. Fertilization — Formation and Structure of the Embryo.

i. Cut off the style and stigma from the gynœcium of a flower of **Datura** or **Œnothera.** Hold it between two layers of elder-pith and cut a series of longitudinal sections. Mount in dilute glycerin, and observe with a low and high power.

Observe :—

a. The *stigma*, made up of thin-walled cells. Note the surface, which is irregular from the production of numerous short hair-like processes (the *stigmatic hairs*).

b. The tissue of the *style*, more or less loosely arranged slightly elongated cells forming the *conducting tissue* of the style.

c. The *pollen grains*, lying upon the stigmatic surface amongst the stigmatic hairs.

d. The *pollen tubes*, projecting from the pollen grains and penetrating amongst the stigmatic hairs, and for a variable distance down the style.

These points may not all be seen in every section, and, if not quite clear, they may be made more obvious by clearing the specimens in potash or allowing them to remain in glycerin for some time. Other flowers may be used for the same purpose.

ii. Cut transverse sections of the ovary of **Viola tricolor** soon after the fading of the petals, or carefully dissect out the ovules of **Datura,** just after fading of the petals. Mount in glycerin.

Observe :—

The *pollen tubes*, lying close to the micropyle of the ovules, or with their extremities within the micropyle and in contact with the nucellus of the ovule.

N.B.—The pollen tube is, morphologically and physiologically, equivalent to the *antherozooids* produced by the male individual of the oophore generation of the Vascular Cryptogamia.

iii. Cut thin transverse sections of the ovary of **Viola tricolor,** so as to obtain the ovules in longitudinal section. Look with a low power for an ovule showing the embryo-sac, then study with a high power.

Observe :—

The production of *endosperm cells* in the parietal layer of protoplasm, by a process of free cell-formation. (*See* " Reproduction of Vegetable Cells.")

iv. Study the flowers of **Primula vulgaris,** with a view to learn the circumstances which affect the conveyance of pollen from the anthers to the stigmas.

Observe :—

a. The corolla of the flower is *bright-coloured* and *conspicuous.* When this is the case the presumption is in favour of some method of *cross-fertilization* by the *agency of insects*, which are thus attracted to the flower.

b. Some of the flowers have *long styles*, the stigma lying at the level of the spreading part of the corolla. In these flowers, the stamens are inserted about half-way down the tube of the corolla.

c. In about an equal number of flowers, the positions of the stigma and stamens are reversed. The styles are *short* and rise to about the level of *half-way* up the tube, whilst the stamens are attached to the *summit* of the tube.

This condition is called **heterostylism,** and it is obvious that the pollen of each of the long-styled flowers cannot reach the stigma of the same flower, and it is experimentally found that pollen from a short-styled flower is incapable of fertilizing a short-styled gynœcium. This is a contrivance to *prevent* self-fertilization. Fertilization in this case is by insects, which *accidentally* convey the pollen from the short-styled flowers to those with long styles, and *vice versa.*

v. Study, with the same object in view, the flower-heads of **Chrysanthemum.**

Observe :—

a. The whole flower-head forms a large conspicuous object, attractive to insects.

b. The outer florets are ligulate and *female*, there being no androecium in them.

c. The inner florets are tubular and *hermaphrodite.*

d. If the flowers are in the proper stage, there will be seen *young* florets in the centre, which present nearly ripe anthers projecting from their summits. Next will be found older florets having similar projecting anthers discharging their pollen ; and more externally still, will be seen florets whose anthers have discharged their pollen, and whose style is seen projecting with its bilobed stigma from the centre of the ring of syngenesious anthers. Here the anthers are ripe *before* the stigma of the same flower is ready to receive the pollen. Obviously, self-fertilization is impossible. Flowers, in which the stamens are ripe first, are said to be **protandrous.**

This condition is very common.

vi. Examine, with the same object in view, the inflorescence of **Plantago major.**

Observe :—

a. The extremely inconspicuous condition of the flowers, giving presumptive evidence that the fertilization is either by the *wind*, or that *self*-fertilization occurs.

b. The flowers are in different stages of development at the upper and lower parts of the inflorescence. When the gynœcium is ripe in the *lower* flowers, neither andrœcium nor gynœcium is ripe in the *upper* flowers. When the andrœcia of the *lower* flowers are ripe, the gynœcia of the *upper* flowers are ripe ; and the andrœcia of the *upper* flowers are ripe when the gynœcia of the *lower* flowers have already been fertilized.

Here the gynœcia are ripe *first.* This kind of flower is called **proterogynous,** and self-fertilization is obviously impossible.

It is obvious also that the *lower* flowers must be fertilized by pollen from another inflorescence, whilst the upper flowers *may be* fertilized by pollen from the lower flowers of the *same* inflorescence.

vii. Take some seeds from the **fruits** of **Capsella bursa pastoris** in various stages of growth, and after noting the characters mentioned at page 148, crush the ovules by gently pressing on the cover slip, and in various specimens make out the stages in the **development of the embryo.**

Observe :—

a. *Stage i.* An elongated row of cells (*suspensor*) terminated by a single globular cell (*embryo cell*).

b. *Stage ii.* The embryo cell divided into *two* vertically.

c. *Stage iii.* The embryo cell divided into *four*, then into *eight*. When divided into eight, there are four upper and four lower cells.

d. *Stage iv.* Subdivision of the lower four cells, so as to form a mass arranged into three series—an outer single layer, *dermatogen ;* a central layer, *plerome ;* and a layer between these, *periblem.* The upper four cells also subdivided into a mass. The upper cell of the suspensor larger than the rest, and called the *hypophysis.*

e. *Stage v.* The outgrowth of two *cotyledons* from the mass belonging to the upper four cells. The mass formed from the lower four cells differentiated into the *radicle.*

f. *Stage vi.* The apical region of the *plumule* formed between the two cotyledons. The hypophysis differentiated into the *calyptra* of the radicle.

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xiv. Varieties of Fruits.

A. Dry dehiscent Fruits.

i. Examine the ripe fruit of **Aquilegia vulgaris.**

Observe :—

a. *Apocarpous* character, consisting of several **follicles,** each made up of pericarp and *seeds.* In each note—

b. Dehiscence *longitudinal*, by opening along the *ventral suture.*

c. Seeds several, borne on ventral suture.

ii. Examine the ripe fruit of **Pisum sativum.**

Observe :—

a. Single carpel, forming the pericarp and enclosing th seeds.

b. Dehiscence *longitudinal*, opening along both *ventral* and *dorsal* sutures.

c. Seeds several, on *ventral* suture.

This fruit is known as the **legume.**

iii. Examine the ripe fruit of **Cheiranthus cheiri.**

Observe :—

a. *Two* carpels, syncarpous.

b. False dissepiment or *replum.*

c. *Longitudinal* dehiscence, by the valve-like separation of the two carpels from the base upwards, leaving the replum and the seeds attached to the parietal marginal placentæ.

This fruit is the **siliqua.**

iv. Examine the ripe fruit of **Capsella bursa pastoris.**

Observe :—

That it only differs from the siliqua of Cheiranthus by being about as broad as long. It is called the **silicula.**

v. Examine the ripe fruit of **Viola tricolor.**

Observe :—

a. *Pericarp,* made up of three syncarpous carpels.

b. *Longitudinal* dehiscence, by the formation of a slit from the summit downwards, in the position of the midrib of the carpels. The pericarp thus splits into three segments, in the middle of the inner face of each of which is a double row of seeds (*parietal marginal*).

This fruit is a **loculicidal capsule.**

vi. Examine the fruit of **Epilobium hirsutum.**

Observe :—

a. Inferior syncarpous fruit with four carpels.

b. *Longitudinal* dehiscence, from above downwards, in such a way as to leave a central column, consisting of the septa, and to divide the pericarp into four segments by slits down the middle of the carpels, each segment bearing a row of seeds.

This fruit is a **septifragal capsule.**

vii. Examine the ripe fruit of **Digitalis purpurea.**

Observe :—

a. *Two* syncarpous carpels.

b. *Longitudinal* dehiscence, by formation of two slits from above downwards in the position of the septa, so as to lead to the separation of the two carpels.

c. Very many seeds on the margins of the carpels.

This is an example of a **septicidal capsule.**

viii. Examine the ripe fruit of **Anagallis Arvensis.**

Observe :—

a. The *transverse* dehiscence, by the formation of a slit around the pericarp separating its upper part as a sort of lid.

b. Numerous seeds on a free central placenta.

This is an example of the **pyxidium** variety of capsule.

ix. Examine the ripe fruit of **Papaver rhœas.**

Observe :—

a. The many-chambered syncarpous character.

b. Dehiscence by the formation of numerous *pores* just beneath the crown-like disk at the summit of the fruit.

This is an example of the **porous capsule.**

B. Dry indehiscent Fruits.

x. Examine the fruit of **Geranium Robertianum.**

Observe :—

a. *In the young fruit*—five *ovaries* at the base, surmounted by a ribbed *beak*, at the summit of which are the five filiform stigmas. It is syncarpous ; each ovary contains a single seed.

b. *In the older fruit*—each ovary containing its seed has separated from the base, and the "ribs of the beak," each really the style of a corresponding carpel, have separated from a central column. Each carpel has become rolled up. The ovaries are indehiscent.

Such a fruit is a **schizocarp.**

xi. Examine the fruit of **Conium maculatum.**

Observe :—

a. *In the young fruit*—two carpels (*syncarpous*), each containing a single seed; on each carpel, note the ridges or *costæ*, five on each carpel, and the *vittæ* or tubular glands, between the ridges. The ovaries are surmounted by the bilobed stigma.

b. *In the older fruit*—each carpel has separated from its neighbour, and is now seen to be borne on the summit of a median septum. Each half of the fruit is known as a *mericarp;* the median septum as the *carpophore ;* and the whole fruit is called a **cremocarp.** It is indehiscent.

xii. Examine the fruit of **Ranunculus.**

Observe :—

a. Many apocarpous carpels. Each consisting of—

b. A thin coriaceous *pericarp*, enclosing—

c. One *seed.*

d. When ripe, each carpel separates from the convex disk.

Such a fruit is an **achene.**

xiii. Examine the fruit of **Corylus Avellana** (Hazel).

Observe :—

a. The leafy investment at the base of the fruit (*cupule*).

b. The *single ovary.* (Originally the gynœcium consisted of a bilocular ovary, but only one seed attains maturity.) It contains a *single seed.*

c. The hard *sclerenchymatous* pericarp.

d. Indehiscent.

This kind of fruit is called the **nut.**

xiv. Examine the fruit of **Acer pseudoplatanus.**

Observe :—

a. *Two* syncarpous carpels, each having—

b. A wing.

c. A hard pericarp ; and containing—

d. A *single seed.*

e. When ripe, the two carpels separate from each other.

This fruit is known as the **samara.**

N.B.—The fruit seen in *Gramineæ*, *e.g.*, wheat, is a variety of achene, in which the pericarp adheres to the testa of the seed. It is called the **caryopsis.** The fruit of Compositæ is another variety of achene, and has a *pappus* of hairs at its summit. It is inferior, and is called the **cypsela.**

C. Succulent Fruits.

xv. Examine the fruit of some species of **Prunus** (Plums, Cherry, &c.).

Observe :—

a. Single carpel, consisting of—

b. *Pericarp.* This is made up of three parts :

1. A thin membranous *epicarp.*
2. The thick succulent *mesocarp.*
3. The thick, hard stony sclerenchymatous *endocarp*, forming the "stone" of the fruit.

c. A *single seed*, inside the "stone" or endocarp.

This kind of fruit is called the **drupe.**

xvi. Examine the fruit of **Ribes grossularia.**

Observe :—

a. *Inferior*, single-chambered.

b. *Pericarp*, consisting of—

1. Thin *epicarp.*
2. Succulent *mesocarp* and *endocarp*, in which are imbedded the seeds.

c. *Seeds* imbedded in the succulent pericarp.

This fruit is the **bacca** or berry.

xvii. The fruit of Apple and Pear consists of a very succulent concave receptacle which surrounds the true fruit after fertilization. They are **spurious** fruits. The Strawberry consists of a number of dry indehiscent achenes inserted on the extremely succulent *torus*, and is also, therefore, a spurious fruit.

XV. Seeds—Germination.

i. Take some seeds of **Phaseolus**, which have been softened by soaking in water for twenty-four hours. Examine them with the naked eye, and dissect them.

Observe :—

a. On one margin of the seed, a dark, rough, elongated oval patch, called the *hilum*. It marks the position of the funicle of the original ovule, and is the point of attachment of the seed to the pericarp of the fruit.

b. The *micropyle*, a minute round opening, near the hilum. It corresponds to the micropyle of the ovule.

c. The outer coat or testa, a thick, tough membrane enclosing the more essential parts of the seed. It is formed from the integuments of the ovule. Carefully strip off the testa. There will then be exposed—

d. The *embryo*, consisting of two large fleshy *cotyledons*, forming the main bulk of the seed, and applied together by their flat surfaces. They are joined together by the other parts of the embryo. At one extremity of the cotyledons is seen the conical *radicle* or young primary root ; it lies outside the cotyledons, and has its apex directed towards the position of the micropyle. Carefully separate one of the cotyledons from its point of attachment to the base of the radicle, and make out the *plumule*, which lies between the cotyledons, and bears rudiments of leaves. The plumule is the young primary stem.

e. Note the *absence* of any *endosperm*. The food material of the seed is deposited in the large fleshy cotyledons.

ii. Cut a series of longitudinal sections of the seed of **Linum usitatissimum.** Mount in glycerin, and examine with a low power. Find a thin median section. In it—

Observe :—

a. The outer brown *testa*, with a thick external cuticle.

b. The *endosperm*—a band of dark-looking tissue, completely lining the interior of the testa, except at the apex of the seed. It is several layers of cells in thickness, and its cells contain oily matters and aleurone grains.

c. The straight *embryo*, lying within the endosperm, and having the same general appearance as the endosperm, but clearly marked off from it. The tissues of the embryo contain oil and aleurone grains. The embryo consists of—

1. Two large *cotyledons*, lying parallel to one another, and occupying the greater part of the seed.
2. The *radicle*, situated at the narrow end of the seed, and with its apex directed towards the micropyle (difficult to make out). The arrangement of the meristematic cells of the apex of the radicle will be found described at page 121.
3. In an accurately median section, the short rounded *plumule* will be seen, lying between the two cotyledons, where their tissues merge into that of the radicle.

iii. The form and relative position of the parts of the embryo are often of classificatory value, *e.g.*, in the **Cruciferæ**. Make out by dissection, and by cutting transverse sections, the characters of the embryo in the following types :—

a. **Helianthus**—embryo straight.

b. **Linum**—embryo straight.

c. **Cheiranthus**—radicle of the embryo bent over so as to lie at one margin of the two flat cotyledons, represented by the diagram. O = (*accumbent*).

d. **Brassica**—radicle of the embryo bent over so as to lie at the side of one of the cotyledons, which are folded so as partly to enclose it, represented by the diagram. O >> (*incumbent* and *folded*).

e. **Capsella bursa pastoris**—radicle of the embryo bent over so as to lie at the side of one of the cotyledons, which is not folded, represented by the diagram. O || (*incumbent*).

f. **Acer pseudoplatanus**—cotyledons rolled up in a scroll-like manner.

iv. Allow some seeds of **Phaseolus** to germinate in moist earth, until the primary root has attained the length of about three inches. Then examine, comparing with the ungerminated seed.

Observe :—

a. The *testa*, ruptured in the region of the micropyle, and still enclosing the two *cotyledons*.

b. The *primary root*, formed by elongation of the radicle of the seed. Note that near the summit there are no secondary roots, whilst, in the more basal parts of the root narrow secondary roots are given off in *four* longitudinal rows.

c. The primary root, continuous above with the cotyledons and also with—

d. The *primary* stem. It is shorter than the primary root (at this stage), and is formed from the plumule, which leaves the seed at a later period than the radicle. Note the young leaves at its summit.

v. Study the changes which take place in the characters and arrangement of the cell contents of the embryo, by cutting sections of the various parts at different stages in germination.

vi. Determine the main **conditions necessary for germination**, by the following experiments :—

A. *Moisture* is necessary.—(*a*) Keep some Phaseolus seeds dry, and (*b*) keep other seeds moist, and both at a temperature of about 35° C. for a week or more, exposed to the air.

Observe :—

(*a*) will *not* have germinated.
(*b*) will have germinated.

B. A certain degree of *temperature* is necessary.—Take three lots of Phaseolus seeds, (*a*), (*b*), and (*c*) ; moisten them all, and keep moist and exposed to the air ; keep (*a*) at a temperature of about 35° C., keep (*b*) at a temperature of about 50° to 55° C., and (*c*) at a temperature of a little over 0° C., for a period of a week or so.

Observe :—

(*a*) *will germinate well.*
(*b*) will *not* germinate.
(*c*) will *not* germinate.

C. *Oxygen* is necessary.

Introduce some Phaseolus seeds, which have well soaked in water, into a bell-jar which has been deprived of its oxygen, as in the ordinary experiment for preparing nitrogen from the atmosphere.

Keep at a temperature of 35° C., and, after a week, compare with other Phaseolus seeds which have germinated in the same conditions of temperature and moisture, in the air.

Observe :—

Those in the atmosphere of nitrogen *do not germinate.*

D. *Light* is *unnecessary.*

Allow two lots of Phaseolus seeds to germinate, one in darkness, the other in light, and observe that there is very little difference in the germination in the two cases.

Light is necessary for *assimilation*, but in the presence of a store of reserve assimilated bodies, as in a seed, growth will occur without light, and continue so long as the store of reserve food lasts.

vii. Determine that, during germination, **heat** is evolved and **carbon dioxide** is formed. Take a glass bottle, place in it some baryta water, then into the neck of the bottle insert a glass funnel. Place in the funnel a number of well-soaked moist Phaseolus seeds, and imbed the bulb of a delicate thermometer amongst the seeds. Cover the whole over with a bell-jar, such as will permit the entrance of some air. Prepare a similar apparatus, but for the seeds substitute some moistened cotton-wool. The object of this is for comparison. Place the two under the same conditions of temperature, and after a few days observe the effects.

Note :—

a. The *temperature* in the apparatus containing the seeds is a degree or two *higher* than the other.

b. There is a cloudiness of the baryta water in the apparatus containing the seeds, and not in the other.

DIVISION B.—MONOCOTYLEDONS.

i. External Characters—Zea mais—Hyacinthus.

i. Examine the general external characters of a fully grown plant of **Zea mais.**

Observe :—

a. *Primary stem*, elongated, large below, tapering above, divided into *nodes* and *internodes*, the former somewhat swollen, the latter smooth and cylindrical.

b. The *leaves*, made up of a very distinct *sheath*, surrounding the stem, and running along it from the node which bears it, sometimes higher than the next node; and a *lamina* or blade, long, flat, broad, and gradually tapering to a point. At the junction of the sheath and lamina there is a small membranous process projecting from the upper side. This is the *ligule*. There is *no petiole*. Note the *parallel venation* of the leaf. Also note the phyllotaxis; it is one-half (see page 128). Only one leaf is borne at each node.

c. The *male inflorescence*, forming a loosely arranged *panicle* of male flowers at the summit of the primary stem. Note the brownish dry scale leaves, which surround the groups of flowers borne on the branches of the panicle (*cataphyllary leaves* or *bracts*).

d. *Branches* of the primary stem. These are only seen in the region of the inflorescence at the summit, and also in the axils of the lower foliage leaves, where they form female inflorescences.

e. *Female inflorescences.* Two or three in number, consisting of secondary axes borne in the axils of the lower leaves. Each is surrounded by a large number of ensheathing leaves, giving to the whole inflorescence a spindle-shaped outline. From the summit of the ensheathing leaves numerous white hair-like processes are seen projecting. On closer examination these are found to be connected with large numbers of sessile female flowers, borne upon a more or less succulent central axis. The female inflorescence is a *spadix* (see page 130). If the plant is older than that described, instead of the female flowers, will be found the characteristic *fruits* of the Maize, clustered upon a central axis.

f. The *roots*. The primary root is short, and not well marked from the secondary roots, which are numerous. (Cf. *Helianthus*.) Very often there may be found (especially towards the end of summer) whorls of *adventitious* roots springing from the lower nodes of the stem.

ii. Carefully examine the external characters of **Hyacinthus**, when in the flowering state.

Observe :—

a. The large numbers of thin, white adventitious *roots*, projecting from the lower part of the bulb. Their structure is described at page 168.

b. The *bulb*.

c. The main stalk or *rachis* of the inflorescence, projecting from the middle of the bulb, and bearing at its summit a raceme of blue flowers.

d. The *flowers*, having pedicels, and each arising from the rachis in the axil of a bract.

e. The sessile green *foliage leaves*.

iii. Examine carefully the **bulb** of **Hyacinthus**, by dissecting it, and by cutting it longitudinally.

Observe :—

a. It consists of a very much abbreviated *primary stem*, which has expanded to form a kind of disk. From the base of it the rootlets are given off. The primary stem bears a large number of imbricated scale-like leaves, which are the expanded bases of the foliage leaves of two or three years' growth.

b. The main flowering stem and the foliage leaves of the present year stand in the axil of the innermost of the scale leaves of *last* year's growth.

c. The leaves belonging to last year, together with the remains of the flowering axis of that year, are found in the axil of the innermost of the scale leaves of the year previous to it.

d. In the axil of the innermost leaf of this present year is found a *bud*, representing the rudiment of next year's stem and leaves. There are thus parts of four distinct years' growth in the same bulb. As the leaves and flowering stem of each year wither off, that of the next begins to take its place, so that the flowering stem of the present year appears to be approximately terminal.

ii. The Stem—Zea mais—Asparagus.

i. Cut thin transverse sections of the **stem of Zea mais.** Mount in glycerin, and examine with a low power.

Observe :—

a. *Epidermis.*

b. *Fundamental tissue*, consisting of—

1. A narrow, interrupted band of small-celled *sclerenchyma* just beneath the epidermis.
2. The general large-celled fundamental tissue, forming the greater part of the tissue of the section. It is *ordinary parenchyma.*
3. A band of *sclerenchyma*, made up of small cells, with very thick walls immediately surrounding each bundle (*external sheath*).

c. *Fibro-vascular bundles*, composed of two parts, xylem and phloëm, and *devoid of cambium* (*closed*). Note—

1. The *position* of the two parts—xylem always *internal*, phloëm external.
2. The *form* of the parts—xylem, more or less V shaped, with its apex directed inwards; phloëm, a small mass lying between the two diverging limbs of the xylem. The arrangement is *collateral*, but *tending* to be *concentric.*
3. The *size* of the bundles—larger in the centre, smaller towards the periphery of the stem.

4. The *number* of the bundles—*large*, but less numerous in the centre of the section.

5. The *general* arrangement of the bundles—they are scattered, *i.e.*, *not arranged in a ring.* (Cf. *Dicotyledon.*)

6. The structure of the *xylem*. The most obvious structures are the large *vessels*. Of these there are *four* to be readily distinguished, two large ones laterally, and two smaller ones internally towards the apex of the V-shaped xylem. The most internal of the latter forms the *protoxylem*. Amongst these four distinct vessels are seen numerous smaller structures (*fibres* and *cells*).

7. The structure of the *phloëm*, made up chiefly of small thin-walled cells, with a few large ones scattered amongst them.

ii. Pick out a thin section, put on your high power, and examine more carefully.

Observe :—

a. *Epidermis* and *cuticle.* Here and there a *stoma* with two *guard cells* and two *subsidiary cells.*

b. The *sclerenchyma* immediately beneath it, made up of small cells with very thick walls and little cell contents.

c. General *parenchyma*—large cells with thin walls and intercellular spaces.

d. *External sheath*, made up of cells like *b*.

e. The *xylem*. The innermost vessel is annular. The next to it is spiral, and the two lateral ones are pitted. Note a space near the innermost vessel (caused by rupture during growth). Around this space are numerous thin-walled small cells (xylem *parenchyma*). Lying around the two large pitted vessels, and at about the middle of the whole bundle, are a few thick-walled small cells (xylem *fibres*).

f. The *phloëm*. It consists chiefly of small thin-walled parenchymatous cells (phloëm *parenchyma*), scattered amongst which are a few larger cells (*sieve tubes*). In some of the latter a sieve plate may be seen.

iii. Cut thin longitudinal sections of the stem of **Zea mais.** Mount in the same way, and examine with a high power

Observe :—

a. The *epidermis*, elongated cells, with a thick *cuticle.*

b. The *sclerenchyma*, made up of narrow thick-walled prosenchymatous cells.

c. The general *parenchyma*, thin-walled cells with intercellular spaces.

d. *Fibro-vascular bundles*, running longitudinally and parallel to each other in the stem. According as the bundle is cut you may have different appearances. Make out—

1. The *annular* vessel.
2. The *xylem parenchyma.*
3. The *spiral* vessel.
4. The *pitted* vessels.
5. The xylem *fibres* with thick walls and simple pits.
6. The *phloëm* made up of phloëm parenchyma, and sieve tubes. In the latter, note the transversely situated *sieve plates.*

e. The *sclerenchyma* of the external sheath, thick-walled cells of prosenchymatous form.

N.B.—The fibro-vascular system may be tabulated thus :—

Phloëm	**parenchyma.**
	vessels (*sieve tubes*).

No cambium.

Xylem	**vessels** (*annular, spiral, pitted*).
	fibres.
	parenchyma.

iv. Compare with the description of **Asparagus** stem (page 33.)

iii. The Leaves.

i. Cut thin transverse sections of the **leaf** of **Zea mais**, including the midrib. Mount in glycerin, and examine with a low, then with a high power.

Observe :—

a. *Epidermis* at the upper surface of the leaf. It consists of more or less flattened cells with a definite external *cuticle.* It bears hairs and contains *stomata.* These are bounded by two small *guard cells* with thickened walls, and at each side is seen a *subsidiary cell* of the stoma.

b. The *fibro-vascular bundles*, lying here and there in the general tissue of the leaf, nearer to the lower surface than the upper. Each bundle has the same structure as in the stem, the phloëm and xylem being arranged in exactly the same way as in the bundle of the stem. The xylem is towards the upper surface.

c. The masses of *sclerenchyma*, lying chiefly beneath the lower layer of epidermis of the leaf, where it forms an interrupted band. The masses of sclerenchyma are most strongly marked opposite to the fibro-vascular bundles, and extend in these situations from the epidermis down to the bundles, forming with the bundles a series of incomplete bands across the leaf.

d. The general *mesophyll*, consisting of parenchymatous tissue, having intercellular spaces. Most of it contains chlorophyll. A single layer of cells of the mesophyll surrounds each bundle, forming a kind of bundle sheath, in which there is no chlorophyll.

e. The section is larger in the region of the midrib, which contains fibro-vascular bundles and a large mass of colourless mesophyll, together with some chlorophyll containing mesophyll near the surface.

f. The lower surface of the section has a sinuous outline corresponding to the fibro-vascular bundles, and is formed by an epidermis similar to that of the upper surface of the leaf.

ii. Cut tangential sections of a leaf of **Zea mais** so as to include only the epidermis of the lower surface of the leaf. Mount in glycerin, and examine with a high power.

Observe :—

a. The *epidermal cells*—flattened plates, oblong in form, with a definite sinuous outline, arranged in rows.

b. The *stomata*, arranged in longitudinal rows amongst the epidermal cells.

c. The *guard cells*, surrounding the stomata—elongated, narrow, and having somewhat thick walls.

d. The *subsidiary cells*, two in number, in connection with each stoma. They are small, and have a triangular form, with their bases applied against the guard cells.

iii. Compare the *stomata* and their *four* surrounding cells, as seen in i. and ii.

iv. Strip off the epidermis from a leaf of **Hyacinthus.** Examine as in ii.

Observe :—

a. Oblong *epidermal* cells.

b. *Stomata.*

c. *Guard cells.*

d. Absence of subsidiary cells.

v. Study the **development of stomata** in the young leaf of **Hyacinthus**, by stripping off the epidermis from various parts of the leaf, beginning at the apex and working downwards. Make out the stages described at page 23.

---

iv. The Root—Hyacinthus—Zea mais.

* i. Cut thin transverse sections of an old root of **Hyacinthus.** Mount in glycerin, and having found a thin section with a low power, put on a high one and examine.

Observe :—

a. *Epidermis.*

b. General *fundamental tissue*, made up of large parenchymatous cells with thin walls and intercellular spaces.

c. The *bundle sheath.*

d. The *fibro-vascular cylinder* in the centre, consisting of—

1. The *pericambium*, a single layer of small thin-walled cells immediately within the bundle sheath.
2. *Xylem masses*, arranged in a radiating manner. They are about six in number. The elements composing them are small towards the periphery, where the *protoxylem* lies, and much larger more internally. In the centre of the cylinder, the xylem masses unite into a single mass, so that there is no central pith. The apex of each radiating mass of xylem abuts on the pericambium.
3. *Phloëm masses.* These are equal in number to the xylem masses, with which they alternate in position. Each has a bright appearance. They are not so distinct as the xylem masses, and are not seen in a young root.
4. The *conjunctive tissue* of parenchymatous cells, filling up all the parts of the cylinder not occupied by the foregoing tissues.
5. Note the absence of any *secondary thickening* and any *cambium.* (Cf. Dicotyledon.)

Cut similar transverse sections of a root of **Zea mais.** Examine in the same way.

Observe :—

a. The same general disposition of the parts as in Hyacinthus.

b. The *xylem masses* are more numerous than in Hyacinthus, and they occupy only the peripheral parts of the fibro-vascular cylinder, so that there is a definite *medulla.*

c. Opposite the xylem masses, the pericambium layer of cells is incomplete, so that the protoxylem abuts upon the bundle sheath.

d. The vessels towards the centre are very large, and those of the protoxylem are small.

iii. In longitudinal radial sections of the root of **Hyacinthus** or of **Zea mais**, make out the characters of the vessels composing the xylem masses.

iv. Cut thin longitudinal median sections of the embryo of the "seed" of **Zea mais**, following the description given at page 42.

Particularly observe :—

a. That the calyptra arises from a special meristem (*calyptrogen*).

b. That the periblem and dermatogen are continuous at the summit into a single *initial layer*.

c. That the plerome arises from cells at its extreme summit, distinct from the initial layer for periblem and dermatogen. (Cf. *Phaseolus*, *Linum*, and *Pinus*.)

v. Make a careful comparative study of the apical regions of the roots of **Pteris, Pinus, Phaseolus, Linum** or **Helianthus,** and **Zea mais.**

v. The Flower—Hyacinthus, &c.

i. Examine the flowers of **Hyacinthus** with the naked eye, and by means of a simple microscope or pocket lens.

Observe :—

a. The *inflorescence*—a raceme.

b. The *bracts*, in whose axils arise—

c. The *pedicels* or flower stalks.

d. The *perianth*, consisting of two whorls of floral leaves, three in each whorl, alternating with those of the other whorl. They are united into a tube (*gamophyllous*), and are free from the gynœcium (*inferior*).

e. The *andrœcium*, consisting of six stamens, separate from each other, and in two whorls of three each. They are inserted on the tube of the perianth (*epiphyllous*). Note the filament and anther.

f. The *gynœcium*, made up of three syncarpous superior carpels. The ovary is *trilocular*, and contains in each chamber two rows of ovules attached to the incurved margins of the carpellary leaves.

g. *Actinomorphic flower.* (*See* page 138.)

ii. Remove in order the various parts of the flowers of **Hyacinthus**, and lay them out in the form of a floral diagram, as at page 139.

Observe :—

a. The whorls contain each *three* leaves, not five (very characteristic of Monocotyledons).

b. The members of each whorl alternate with those of the whorls externally and internally.

c. If the position of the *median plane* (*see* page 139) be marked, it will be found that the outermost ring of leaves of the perianth has a single anterior leaf and two posterior ones.

d. Carefully compare with the diagram of *Geranium* (page 139).

iii. Cut thin transverse sections of the anthers of a flower bud of **Lilium.** Mount, and examine with a low and high power.

Observe :—

The structure of the anther, and the nature of the pollen, which are essentially the same as that described at page 142.

iv. Cut thin transverse sections of the ovary of **Lilium** which has been kept in spirit for some time. Mount in glycerin, and examine with a low power.

Observe :—

a. Three syncarpous carpels.

b. The incurved margins of the carpels at the centre of the ovary.

c. The *anatropous* ovules, two rows in each carpel.

d. In the **ovule** make out—

1. The *funicle.*
2. The two *integuments.*
3. The *micropyle.*
4. The *nucellus,* within which, in a fortunate section may be seen—
5. The *embryo-sac,* containing—
6. The *oosphere* and *synergidæ,* and the *antipodal cells.*

e. Make a careful drawing, and compare with the description at page 147.

v. Make out, and write, a **floral formula** for *Hyacinthus* or *Lilium.*

It is:—

$$K\ 3,\ C\ 3,\ A\ 3 + 3,\ G\ \underline{3}.$$

vi. Examine the flower of **Orchis maculata.**

Observe:—

a. *Zygomorphic* character. (*See* page 138.)

b. *Inferior* twisted ovary.

c. Conspicuous *perianth,* suggesting insect fertilization.

d. Andrœcium, consisting of a single *stamen,* having a bilocular anther, united to the gynœcium in the upper part (*gynandrous*). Two other imperfect stamens, not bearing anthers, and called *staminodia,* are present.

e. The two lobes or halves of the anther: each contains a pear-shaped body, consisting of a mass of pollen grains held together by some mucilaginous material, and called a *pollinium.*

---

vi. The Fruit and Seed—Zea mais, &c.

i. Examine the so-called *seeds* (really **fruits**) of **Zea mais.**

Observe:—

a. The outer coat of the fruit, which consists of *pericarp* and *testa.*

b. The large mass of *endosperm*, yellow and hard at the surface, softer and white in the interior.

c. The *embryo*, a small white body lying at one side of the seed.

The fruit is a special modification of the *achene*. (*See* page 156.)

ii. Having noted the position of the embryo, cut longitudinal sections of the fruit in such a way as to longitudinally cut the embryo. Mount in glycerin, and examine with a low power.

Observe :—

a. The *pericarp* of the fruit, closely adherent to—

b. The *testa* of the seed.

c. The *endosperm*, consisting of thin-walled cells containing protoplasm, in which are imbedded numerous closely compressed polygonal starch grains. Note the peripheral hard yellow, and the softer inner white endosperm.

d. The *embryo*, which lies at one side, closely attached to the endosperm. In the embryo note—

1. The single *cotyledon*, which extends over the whole surface of contact of the embryo with the endosperm.
2. A portion of the embryo, continuous with the cotyledon, which almost completely surrounds the rest of the embryo, and is called the *scutellum*.
3. The *plumule*, or rudimentary stem of the embryo, covered by several young sheathing leaves.
4. The *radicle*, consisting of tissues arranged into a plerome, periblem, and dermatogen. It is covered by a root cap, which arises from a special layer of *calyptrogen* outside the dermatogen. (*See* page 42.)
5. Outside the root cap and continuous with it, is a root sheath or *coleorhiza*.

iii. Allow some "seeds" of **Zea mais** to germinate, and compare the young plants at various stages with the "seed."

Observe:—

a. The fruit swells by imbibition of water, and bursts in the region of the embryo, the rupture beginning opposite the apex of the radicle.

b. The *radicle* makes its way through this rupture, and in doing so bursts through the caleorhiza, which appears as an irregular ring round the base of the young root.

c. The *plumule* also protrudes from the seed, and becomes the young primary stem.

d. The young root, and also the tissue above the scutellum, gives origin to *secondary* roots which very soon equal, and even exceed, the primary root in growth. (Cf. Dicotyledons.)

iv. The general physiology of germination of the **Zea mais** may be studied in the same way as that of Phaseolus. (*See* page 159.)

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